U. S. FOREST SERVICE
RESEARCH PAPER NC-1
FEBRUARY 1966

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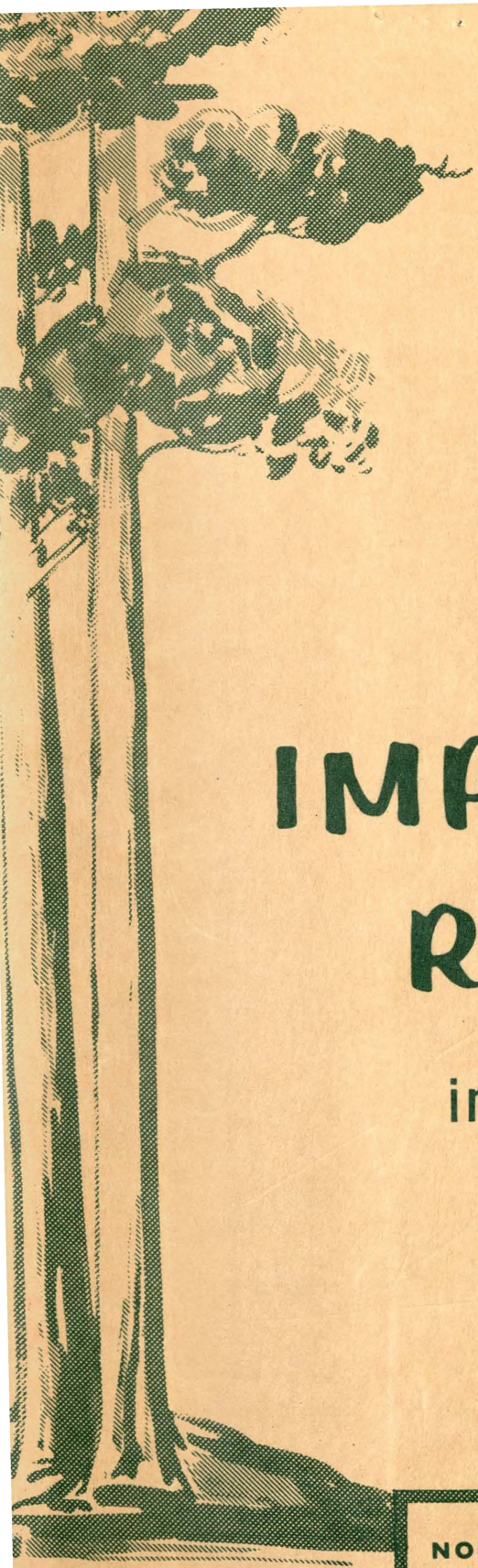

FOREST TREE IMPROVEMENT RESEARCH

in the Lake States, 1965

BY
PAUL O. RUDOLF

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

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FOREWORD

In June 1957 the Lake States Forest Tree Improvement Committee directed its Research, Evaluation, Coordination, and Planning (RECAP) Subcommittee to assemble project summaries for the agencies doing forest tree improvement research in Michigan, Minnesota, and Wisconsin. This information was published in 1959 as Station Paper 74 of the Lake States Forest Experiment Station.

Between 1959 and 1965 there has been a considerable expansion of tree improvement research and a beginning of developmental work in the Lake States. New projects have been initiated and some old ones terminated, and new workers and some additional agencies have entered the field — for these reasons a new survey seemed desirable. Accordingly the Lake States Forest Tree Improvement Committee charged its RECAP Subcommittee (Burton V. Barnes, University of Michigan; Dean Einspahr, Institute of Paper Chemistry; Fred Knight, University of Michigan; H. L. Mitchell, Forest Products Laboratory; R. F. Patton, University of Wisconsin; Jonathan W. Wright, Michigan State University; and Paul O. Rudolf, North Central Forest Experiment Station, Chairman) to make a new survey and directed the Subcommittee Chairman to assemble, process, and distribute the report. In the interests of uniformity, we decided to follow the pattern of the 1959 report which, in turn, was similar to that of a western report published by the Forest Genetics Research Foundation.

The present report describes 133 research projects being conducted by 12 agencies, and 8 developmental tree improvement projects being conducted by 4 agencies. We believe that this survey gives a reasonably good account of present forest tree improvement research and development work in the Lake States. A comparison with the 1959 report shows how tree improvement activities in the Lake States have grown and the direction in which the growth is taking place. This report may also help to chart the way we should go in the future. It is presented for the consideration of those conducting or supporting forest tree improvement research or development work and of others interested in the work.

Some projects are being conducted by two or more research agencies. Such a project is described in detail only under the originating agency; but it is also listed under the other agency's project number.

A number of nonresearch organizations have aided some research projects through providing land, field help, nursery facilities, seed, or other items. They are listed as cooperators. Furthermore, a few forest land management agencies have initiated tree improvement developmental work. Because this work still is rather closely related to research work, such projects are listed here, but in a separate category. One participant has projects listed in both the research and the developmental categories.

The RECAP Subcommittee gratefully acknowledges the assistance of the agencies and workers who gave their time generously in preparing the project statements and of the North Central Forest Experiment Station in publishing this report.

Paul O. Rudolf, Chairman
Research, Evaluation, Coordination
and Planning Subcommittee

In 1959 the Lake States Forest Experiment Station published Station Paper No. 74 for the Lake States Forest Tree Improvement Committee. This initial summary of forest tree improvement research being done by many agencies in the region has served a useful purpose. We believe that the revision should prove equally useful, and we are glad to continue fostering the work of the Lake States Forest Tree Improvement Committee by publishing another of its reports.

D. B. King, Director
North Central Forest Experiment Station[1]

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[1] *At the end of 1965, parts of the areas formerly served by the Lake States Forest Experiment Station and the Central States Forest Experiment Station were combined to form the area now served by the North Central Forest Experiment Station. The new Station is responsible for conducting federal forest research in Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin. The North Central Station maintains its headquarters on the St. Paul Campus in cooperation with the University of Minnesota.*

Forest Tree Improvement Research in the Lake States - 1965

A Survey

by the Lake States Forest Tree Improvement Committee

Edited by Paul O. Rudolf[1]

THE PATTERN OF THE PROJECT DESCRIPTIONS

In this report each current or recently completed forest tree improvement project in the Lake States is described in a brief statement prepared either by the person in charge of the study or under his direction. Each statement consists of the project title; a brief description of the objectives, methods, and accomplishments; a list of cooperators (if any); and the names and titles of those responsible for the study.

Each statement bears two sets of numbers, one preceding and one following the title. Some bear a third set of numbers in parentheses at the end of the title line. The numbers preceding the title are for identification of the project in any cross-references and in the indexes at the end of the report. The first number identifies the agency, and the second, following a hyphen, the project under that agency. The numbers following the title show the subject-matter category or categories of the project. These categories follow a classification prepared by Scott S. Pauley. The classification is given on page 50. The third set of numbers, where present, provides the number that was used to identify the project, or some part of it, in the 1959 report.

In the title line each statement shows the scientific names of the tree species being studied. Sometimes only the genus is identified. Occasionally the word "General" is used instead of the species name to indicate broad projects applying to several genera.

[1] *Chairman, Research Evaluation, Coordination, and Planning Subcommittee of the Lake States Forest Tree Improvement Committee; and Principal Silviculturist, North Central Forest Experiment Station, St. Paul, Minn., 55101.*

AGENCIES INVOLVED

In Research

Code No.	*Name*
1	Consolidated Papers, Incorporated
2	The Institute of Paper Chemistry
3	Michigan State University
4	Michigan Technological University
5	Minnesota Department of Conservation
6	Nekoosa-Edwards Paper Company
7	Quetico-Superior Wilderness Research Center
8	U.S. Forest Service, Forest Products Laboratory
9	U.S. Forest Service, Lake States Forest Experiment Station[2]
10	University of Michigan
11	University of Minnesota
12	University of Wisconsin

In Development

Code No.	*Name*
13	Kimberly-Clark Corporation
14	The Mando Division of the Boise Cascade Corporation
15	Nekoosa-Edwards Paper Company
16	U.S. Forest Service, North Central Region

[2] *Beginning in 1966, the area formerly covered by the Lake States Forest Experiment Station is administered by the North Central Forest Experiment Station. However, the designation, "Lake States Forest Experiment Station," is used throughout the report since activities were conducted by that Station under that name.*

RESEARCH PROJECTS

1. Consolidated Papers, Incorporated

(P. O. Box 158, Rhinelander, Wis. 54501)

1-1. Super Spruce Planting. 111.3, 122. *Picea glauca.* (1-1)

Object: To determine whether fast-growing white spruce nursery stock continues superior growth after being transplanted into the field, and also whether superior growth is indicative of superiority in other desirable categories; eventually to use this planting as a seed orchard if superior genetic characteristics appear to be involved.

Methods: Exceptionally fast-growing 2-2 white spruce stock was chosen from the company's Monico nursery in 1950 and 1956 and was field planted with controls.

Accomplishments: Recent measurements of the 1950 plantings indicate that the average super spruce is nearly 3 feet taller than the average control tree. Of 394 survivors each of both super spruce and controls, 242 super spruces are 10 feet or over while only 103 controls have reached this height. The super spruces planted in 1956 are considerably more resistant to late spring frost damage than are controls, but whether this is a direct genetic factor or merely the result of extra height is subject to further testing.

Cooperators: Lake States Forest Experiment Station.

Assignment: J. W. Macon and N. S. Stone, foresters.

2. The Institute of Paper Chemistry

(Appleton, Wis. 54910)

2-1. Larch Improvement. 111, 112.01. *Larix decidua, L. decidua* var. *polonica, L. eurolepis, L. gmelini* var. *japonica, L. gmelini* var. *koreana, L. leptolepis, L. sibirica.* (2-1)

Object: To field-test proveniences of larch species and larch hybrids as a partial evaluation of the suitability of this fast-growing conifer for intensive production of raw material for pulping and papermaking.

Methods: Stock of various sources was grown in the nursery and then outplanted. Measurements on survival, growth, and wood quality are to be taken periodically.

Accomplishments: Seedlings of the above species and hybrids have been planted out near Clintonville and Eagle River, Wis. Annual measurements have been summarized for the oldest plantings since 1957 and the youngest plantings since 1961. Drought and frost have reduced growth and survival of the 1961 plantings.

Cooperators: American Can Co.; Kimberly-Clark Corp.; Nekoosa-Edwards Paper Co.; The Northwest Paper Co.; Owens-Illinois, Inc., Forest Products Division; The Procter & Gamble Company; St. Regis Paper Company; Scott Paper Company; Thilmany Pulp and Paper Co.; David B. Cook, Cooxrox Forest, N.Y.

Assignment: Miles K. Benson, Research Aide; Dean W. Einspahr, Research Associate.

2.2. The Application of Pulping and Papermaking Sciences to the Genetic Improvement of Southern Pulpwood. 151.32, 121. *Pinus taeda.* (2-3)

Object: To contribute to the genetic improvement of southern pulpwood species by: (1) expanding fundamental knowledge about primary wood characteristics in relation to papermaking and (2) evaluating the pulping potential of selected parent clones.

Methods: For a number of high and low specific gravity clones of loblolly pine 10-mm increment core samples and micropulping techniques are being used to provide measurement data on specific gravity, fiber dimensions, percent summerwood, extractives, lignin, pulp yield, and fiber strength (zero-span tensile strength). Whole-tree pulping on some of the trees will provide, in addition to the above data, information on tearing strength, bursting strength, and tensile strength for each of the clones being studied.

Accomplishments: The trees have been sampled, micropulping and whole-tree pulping have been completed, and the data are being evaluated.

Cooperators: Forest Genetics Laboratory, Texas Forest Service.

Assignment: Dean W. Einspahr, Research Associate, Genetics and Physiology Group; and John R. Peckham, Research Aide, Engineering and Technology Section; both of the Institute of Paper Chemistry; J. P. van Buijtenen, Forest Genetics Laboratory, Texas Forest Service.

2-3. Lake States Aspen Genetics and Tree Improvement Project. 211, 212, 251.32. *Populus deltoides, P. grandidentata, P. tremuloides.* (2-4)

Object: To explore and develop the genetic potential of aspen species and cottonwood for achieving maximum production of high-quality fiber for pulp and papermaking.

Methods: Desirable breeding materials are being developed through the use of the techniques of selection, hybridization (intra- and inter-specific), polyploid discovery and induction, and radiation-induced mutations. Research areas receiving major attention include: (1) wood properties influencing processing variables and paper properties, (2) heritability of growth and morphological characteristics, (3) heritability of wood and fiber properties, (4) polyploid induction, (5) sexual and vegetative propagation techniques, (6) wood property evaluation from small samples, (7) field establishment of improved materials, and (8) establishment of "base lines" for judging wood quality and tree growth through the use of studies of natural variation.

Accomplishments: Superior aspen phenotypes, including natural triploids in Michigan, Wisconsin, Minnesota, and Canada, have been discovered. Since 1956, 162 controlled crosses have been successfully completed and are being field tested. Variation in growth and in morphological and wood properties has been studied and heritabilities estimated. Methods of mass producing hybrid aspen seed and seedlings have been developed. Wood properties and pulping properties of triploid aspen have been investigated. Within-tree and between-tree variation in wood properties have been studied.

Cooperators: Louis W. and Maud Hill Family Foundation; American Can Co.; Kimberly-Clark Corp.; Nekoosa-Edwards Paper Co.; The Northwest Paper Co.; Owens-Illinois, Inc., Forest Products Division; The Procter & Gamble Co.; St. Regis Paper Co.; Scott Paper Co.; Thilmany Pulp and Paper Co.

Assignment: Dean W. Einspahr, Research Associate; Lawson L. Winton, Research Aide; Miles K. Benson, Research Aide.

2-4. Quaking Aspen Geographic Variation. 211.1, 251.32, 251.4. *Populus tremuloides.*

Object: To increase our knowledge of the natural variation of wood, fibers, and growth characteristics and to accumulate data needed for establishing "base lines" for judging wood quality of quaking aspen.

Methods: Studies on natural stands in five geographic locations within the State of Wisconsin and Upper Michigan were initiated in 1963. Five stands were sampled in each area and measurements included: (1) age, form, and growth information on the studied trees, (2) specific gravity and fiber length based on four 10-mm. increment cores, (3) soil and other site information based on soil samples taken from the A and B horizons, (4) pulping information (fiber strength, pulp yield, extractives, and lignin) for one stand within each geographic area, using 10-mm. increment cores and a special micropulping procedure.

Accomplishments: Field sampling of the five geographic areas has been completed, increment core samples have been evaluated, micropulping has been completed, and the data obtained are being analyzed.

Cooperators: Louis W. and Maud Hill Family Foundation; American Can Co.; Kimberly-Clark Corp.; Nekoosa-Edwards Paper Co.; The Northwest Paper Co.; Owens-Illinois, Inc., Forest Products Division; The Procter & Gamble Co.; St. Regis Paper Co.; Scott Paper Co.; Thilmany Pulp and Paper Co.

Assignment: Dean W. Einspahr, Research Associate; Miles K. Benson, Research Aide.

2-5. Nutrient Requirements of Aspen Hybrids. 212.0, 251.03. *Populus canescens, P. grandidentata, P. tremuloides.*

Object: To investigate the relative nutrient requirements of a number of aspen hybrids in relation to the requirements of seedlings of the parent species.

Methods: Seedlings from controlled crosses (*tremuloides* x *canescens*, *canescens* x *tremuloides*, *grandidentata* x *canescens*, and *canescens* x *grandidentata*) will be grown on nutrient solutions, using an automatically controlled sand culture system. Growth studies will be conducted in a controlled-environment growth room. Nitrogen, P, K, Ca, and Mg will be varied in an effort to establish required nutrient levels for the above aspen crosses and aspen hybrids.

Accomplishments: The necessary experimental crosses have been completed, and the growth chamber experimental runs are underway.

Cooperators: Louis W. and Maud Hill Family Foundation; American Can Co.; Kimberly-Clark Corp.; Nekoosa-Edwards Paper Co.; The Northwest Paper Co.; Owens-Illinois, Inc., Forest Products Division; The Procter & Gamble Co.; St. Regis Paper Co.; Scott Paper Co.; Thilmany Pulp and Paper Co.

Assignment: Dean W. Einspahr, Research Associate; Miles K. Benson, Research Aide.

2-6. Aspen Improvement — Cytology. 222, 251.1. *Populus deltoides, P. tremuloides.*

Object: To determine the time after pollination of fertilization and embryo initiation.

Methods: During the spring of 1965, female-catkin bearing branches were forced in the greenhouse and growth chamber. After pollination, de-

veloping capsules were collected at specified times until seed was shed. Capsules were then embedded and sectioned.

Accomplishments: Preliminary cytological investigations indicate that the time of fertilization and embryo initiation may be estimated in the greenhouse from phenotypic observations. This would permit the application of chemical or other environmental stimuli during the desired, critically receptive period.

Cooperators: Louis W. and Maud Hill Family Foundation; American Can Co.; Kimberly-Clark Corp.; Nekoosa-Edwards Paper Co.; The Northwest Paper Co.; Owens-Illinois, Inc., Forest Products Division; The Procter & Gamble Co.; St. Regis Paper Co.; Scott Paper Co.; Thilmany Pulp & Paper Co.

Assignment: Lawson L. Winton, Research Aide; Dean W. Einspahr, Research Associate; Miles K. Benson, Research Aide.

2-7. Aspen Tissue Culture Studies. 251.1, 251.0, 251.04, 221. *Populus* spp.

Object: To investigate the usefulness of tissue culture techniques in studying the physiology and cytology of tree growth and differentiation.

Methods: Cambial tissue is isolated and grown *in vitro* under a variety of environmental conditions. Growth and differentiation are measured and recorded, using accepted statistical, chemical, and cytological techniques.

Accomplishments: This work has been underway since 1962. Accomplishments include: (1) development of a suitable coconut-milk medium, both liquid and agar, for maintaining actively growing aspen tissue, (2) discovery of the production of antimicrobial substance by actively growing aspen tissues, (3) investigation of correlations between rate of tree growth and callus production, (4) completion of preliminary studies on techniques for inducing the differentiation of roots and shoots on isolated callus tissue, and (5) isolation and propagation of a number of clonal lines of aspen tissue.

Cooperators: Pioneering Research Committee.

Assignment: Lawson L. Winton, Research Aide (succeeded Martin C. Mathes, September 1964); Dean W. Einspahr, Research Associate.

3. Michigan State University, Forestry Department

(East Lansing, Mich. 48824)

3-1. Provenance Tests. 111.1, 211.1. *Abies concolor, Larix laricina, L. leptolepis, Picea abies, P. glauca, P. rubens, Pinus banksiana, P. flexilis, P. nigra, P. ponderosa, P. resinosa, P. strobiformis, P. strobus, P. sylvestris, P. virginiana, Populus deltoides, Pseudotsuga menziesii, Quercus robur, Q. rubra.* (3-3, 3-4, 3-5, 3-6)

Object: For important forest tree species, to determine the pattern of variation and the best sources for planting in specified localities; to determine the evolutionary and physiological factors responsible for the variation; and to furnish material for future breeding work.

Methods: From 25 to 200 seedlots of a species are obtained, preferably from the entire range (from the best portion of the range if there has been a previous range-wide test). Each seedlot is from several trees in a native stand. The seedlots are grown and measured in a replicated nursery test, then outplanted at several locations. The genetically variable traits are measured at variable intervals. Increasingly, the growth measurements are treated as routine, and greater emphasis is placed on variation in foliar chemistry, flowering habits, and other traits.

Accomplishments: The Scotch pine experiment, started in 1959, is the most completely studied. The species is composed of about 21 geographic varieties, recognizable on the basis of phenotype or performance in test plantations. Following are the regions from which extreme progenies came: fastest growth — northern France; slowest growth — northern Finland and Siberia; yellowest and greenest winter foliage — Ural Mountains and Spain respectively; greatest resistance to European pine sawfly — Ural Mountains and southern Sweden; least winter hardy — Spain; least resistance to webworm — Turkey and Greece; earliest flower production (19 percent of trees by age 7) — England; lowest nitrogen — Spain; largest percentage of forked buds — Scotland. A 13-element foliar analysis gives some clues as to the physiological reasons for differences in growth rate, flower production, and sawfly resistance. Over the State of Michigan there is relatively little interaction between genotype and test site in three growth characters. The root systems of the various races differ almost as much as do the tops but are difficult to study except in 1-year material.

Growth data as complete as those for Scotch pine are also available for the other species, but other chemical analyses and root studies have not yet progressed as far. The stories in these other species vary. In all except red pine, the amount of geographic variation is considerable. In some there are clines, in some random variation, and in some distinct races. Usually, a race other than the native one is fastest growing, although the native one is among the fastest growing. Where correla-

tion was possible, there has usually been a high degree of correlation between 1- or 2-year performance and performance up to age 8. In white pine the determination of the best general area (southern Appalachians) for seed procurement has reached the stage where a more intensive 1-region provenance test has been started. The following papers report some of the accomplishments:

King, James P. 1965a. Seed source X environment interactions in Scotch pine. I. Height growth. Silvae Genetica 14: 105-115.

————————. 1965b. Seed source X environment interactions in Scotch pine. II. Needle length and color. Silvae Genetica 14: 141-185.

Ruby, John L. 1964. The correspondence between genetic, morphological, and climatic variation patterns in Scotch pine. Ph.D. thesis, Mich. Station.

Steinhoff, R. J. 1964. Taxonomy, nomenclature, and variation within the *Pinus flexilis* complex. Ph.D., thesis, Mich. Station.

Wells, O. O. 1964a. Geographic variation in ponderosa pine. I. The ecotypes and their distribution. Silvae Genetica 13: 89-103.

————————. 1964b. Geographic variation in ponderosa pine. II. Correlations between progeny performance and characteristics of the native habitat. Silvae Genetica 13: 125-132.

Wright, J. W. and W. I. Bull. 1962. Geographic variation in European black pine — 2-year results. Forest Science 8: 32-42.

———————— and ————————. 1963. Geographic variation in Scotch pine — results of a 3-year Michigan study. Silvae Genetica 12: 1-25.

Wright, J. W., W. I. Bull, and Gero Mitschelen. 1963. Geographic variation in red pine — 3-year results. Mich. Agric. Expt. Sta. Quart. Bul. 45(4): 622-630.

Wright, J. W., W. Lemmien, and J. Bright. 1963. Geographic variation in eastern white pine — 6-year results. Mich. Agric. Expt. Sta. Quart. Bul. 45: 691-697.

Arend, J. L., N. F. Smith, S. H. Spurr, and J. W. Wright. 1961. Jack pine geographic variation — five-year results from Lower Michigan. Mich. Acad. Sci. Papers 1961. 46: 219-238.

Cooperators: NC-51 members (Iowa State University; Kansas State University; Ohio Agricultural Experiment Station; Purdue University; South Dakota State University; Universities of Illinois, Minnesota, Missouri, Nebraska, and Wisconsin; Lake States Forest Experiment Station;)[3] Michigan Department of Conservation; and research agencies in Ontario, Pennsylvania, Maryland, and Germany.

[3] *The NC-51 Committee is the North-Central Regional Tree Improvement Committee. It consists of representatives of the land-grant universities of the North-Central States, the U.S. Forest Service, and the U.S. Cooperative State Experiment Station Service.*

Assignment: J. Bright, Forester; W. Lemmien, Forester; W. I. Bull, Associate Professor; M. W. Day, Assistant Professor; and J. W. Wright, Associate Professor; and graduate students J. P. King, J. L. Ruby, J. Brown, W. K. Randall, R. W. Hilton, K. Steinbeck, R. Steinhof, and J. Tobolski.

3-2. 1-Parent Progeny Tests. 111.3, 112.02, 122.1, 141. *Pinus banksiana, P. resinosa, P. strobus, P. sylvestris.*

Object: To learn the inheritance of economic traits, select the best parents for breeding, determine local variation patterns, and establish seed orchards as an integral part of a theoretical-practical improvement program.

Methods: The work was started in 1960, and a new species has been added about every 2 years. From 125 to 1,000 1-parent progenies (only mother tree known) are included in each experiment, which is first run through a replicated nursery test, then planted at 3 to 6 locations in the State. The parents in some species were randomly selected, and in others very carefully selected for three most important traits. In the largest, the jack pine experiment, the initial 1,000 progenies will be reduced to 250 on the basis of nursery performance before being field planted. The experiments will run for 40 or 50 years. At about age 8 or 10 a second generation will be started, using the best trees in the progeny tests now being established. In the second generation control-pollinated progenies will be used, so that both parents can be known.

Accomplishments: All except the jack pine experiment have been outplanted successfully, with survivals of 85 to 90 percent. The jack pine is still in the nursery stage. Early height measurements indicate that most of the variation is associated with stand rather than mother-tree within stand. Differences in other traits have not been large when the seed was collected from a limited area such as southern Michigan. Some accomplishments are reported in:

Wright, J. W. 1963. Genetic variation among 140 half-sib Scotch pine families derived from 9 stands. Silvae Genetica 12: 83-89.

Cooperators: North Central Region, U.S. Forest Service; Michigan Department of Conservation.

Assignment: J. W. Wright, Associate Professor; David Canavera, Graduate Assistant.

3-3. The Genetics of Physiological Differences. 151.0, 111.1, 111.0, *Pinus banksiana, P. nigra, P. sylvestris.*

Object: To determine the underlying physiological mechanism behind external growth characters.

Methods: Using material in existing provenance tests, chemical analyses are made. The basic analyses planned for this year are of the volatile terpenes (gas chromatograph) and the mineral elements in the foliage (mass spectrograph). Also,

growth chambers are used to subject different races to known photoperiod, temperature, and light intensity regimes.

Accomplishments: In nearly all of 13 elements there were strong genetic differences within Scotch and European black pines. Multiple-regression analyses furnished some clues as to the mechanism of growth characters. In Scotch pine, the transition from yellow winter to green summer foliage was found to be conditioned by daytime temperature (above 60° F. for three days), light (no change in the dark), and moisture. Night temperature did not matter. The following paper reports some accomplishments:

Steinbeck, Klaus. 1965. Foliar mineral accumulation by several Scotch pine (*Pinus sylvestris* L.) provenances. Ph.D. thesis, Mich. Station.

Assignment: J. W. Wright, Associate Professor; D. P. White, Associate Professor; James Tobolski and R. Hilton, Graduate Assistants.

3-4. Improvements in Methodology. 153, 154. General.

Object: To reduce the amount of work in genetic experimentation by 95 percent without affecting results, or alternatively to increase the data yield 20-fold without affecting effort.

Methods: The basic method is to question every current practice and try to improve it. Some of the emphasis is on improved gadgetry. More is on the philosophy of planning, measurement, and analysis, in an effort to eliminate wasted procedures. Generally, problems are tackled as they arise in other phases of the program.

Accomplishments: A machine-planting technique was perfected so that on suitable sites small-plot experiments can be machine planted (at a rate of about 5,000 trees per day) with straight rows in both directions, high survival, and better weed control than with hand planting.

The theory and practice of plot size were investigated to determine what experimental designs would be most suitable for various types of experiments. For the provenance tests 4-tree plots seem best. For the 1-parent progeny tests, 8- to 10-tree linear plots seem more suitable.

A record system was evolved which handles all measurements taken on a single planting and makes prompt analysis feasible. A few measurement shortcuts can lop off 50 to 75 percent of measurement time.

By the use of correlation it was found that most seedlots need not be measured at every place when a given experiment is repeated at several localities. Frequently 90 percent of the important information can be obtained by detailed measurement of one such outplanting plus careful observation in others and plus detailed measurements of a few key seedlots.

Assignment: J. W. Wright, Associate Professor.

4. Michigan Technological University, Department of Forestry

(Houghton, Mich. 49931)

4-1. Japanese Larch Seed Source Study. 111.1. *Larix leptolepis.*

Object: To determine the variability within the species and the best origins to plant in Upper Michigan. (See study 3-1.)

Methods: Seedlings from 8 sources were outplanted in 1961.

Accomplishments: Survival was poor for all sources.

Cooperators: Michigan State University.

Assignment: Peter Garrett, Assistant Professor.

4-2. White Spruce Seed Source Study. 111.1 *Picea glauca.*

Object: To observe the range of genetic variability in a range-wide study. (See studies 9-13 and 3-1.)

Methods: Planted in 1963 were seedlings from 25 sources covering a major portion of the natural range of the species.

Accomplishments: The trees were scored for height growth, frost injury, winter kill, and insect damage in 1965. Late spring frosts caused heavy damage to current leaders in most sources.

Cooperators: Michigan State University, Lake States Forest Experiment Station.

Assignment: Peter Garrett, Assistant Professor.

4-3. White Spruce Seed Source Study. 111.1 *Picea glauca.*

Object: To observe the range of genetic variability in several Upper Michigan sources. (See study 9-14.)

Methods: Seedlings from 25 sources in Upper Michigan were planted in 1963.

Accomplishments: Trees were scored for height growth, frost injury, and insect damage in 1965.

Cooperators: Lake States Forest Experiment Station.

Assignment: Peter Garrett, Assistant Professor.

4-4. European Black Pine Seed Source Study. 111.1. *Pinus nigra.*

Object: To determine the maximum range of genetic variability within this species and the best origins to plant in Upper Michigan. (See study 3-1.)

Methods: Seedlings from 15 European and Asiatic sources were planted in 1961. Height and mortality were recorded in 1965.

Cooperators: Michigan State University.

Assignment: Peter Garrett, Assistant Professor.

4-5. Ponderosa Pine Seed Source Study. 111.1. *Pinus ponderosa.*

Object: To determine the variability within the species and the best sources from which to obtain seed for planting in Upper Michigan. (See study 3-1.)

Methods: Seedlings from 12 sources were outplanted in 1963.

Accomplishments: Height growth, frost damage, and winter kill were scored in 1965.

Cooperators: Michigan State University.

Assignment: Peter Garrett, Assistant Professor.

4-6. Red Pine Seed Source Study. 111.1. *Pinus resinosa.*

Object: To determine the best regions from which to collect seed for planting in Upper Michigan and to observe variation between sources. (See study 3-1.)

Methods: Seedlings from 24 sources were planted in 1963. Height, frost damage, and winter kill were recorded in 1965.

Cooperators: Michigan State University.

Assignment: Peter Garrett, Assistant Professor.

4-7. Eastern White Pine Seed Source Study. 111.1. *Pinus strobus.*

Object: To determine the natural range of variability and to select the best sources from which to collect seed for planting in Upper Michigan. (See study 3-1.)

Methods: Seedlings from various sources were lined out for one season and will be outplanted in fall of 1965.

Cooperators: Michigan State University.

Assignment: Peter Garrett, Assistant Professor.

4-8. Scotch Pine Seed Source Study. 111.1 *Pinus sylvestris.*

Object: To determine the best regions from which to obtain seed for future planting in Upper Michigan. (See study 3-1.)

Methods: Seedlings from 80 European and Asiatic sources were outplanted in 1961. Observations on various characters are recorded periodically.

Accomplishments: The trees were scored for height growth and foliage color in fall of 1963. Significant differences were noted in both features. Trees will be scored in 1965 for winter injury, forking, and height growth.

Cooperators: Michigan State University.

Assignment: Peter Garrett, Assistant Professor.

4-9. Range-Wide Sugar Maple Provenance Study. 211.1. *Acer saccharum.*

Object: (1) To inquire into the nature and extent of genetic variation within and between provenances throughout the species range, and (2) to compare juvenile and mature performances within provenances.

Methods: Seed from 32 natural stands of sugar maple was collected in 1964. Trees are now growing in nursery beds.

Cooperators: Northeastern Forest Experiment Station.

Assignment: Peter Garrett, Assistant Professor.

4-10. Wood Quality in Sugar Maple. 251.32. *Acer saccharum.*

Object: To determine the range of variability of wood characteristics that may affect wood quality in sugar maple.

Methods: Large-diameter increment cores will be taken throughout the natural range of sugar maple in northern Michigan. Initially, variation in specific gravity, shrinkage, spiral grain, and fiber characteristics will be determined.

Accomplishments: Sampling is in progress.

Assignment: Robert L. Sajdak, Instructor.

5. Minnesota Department of Conservation, Division of Forestry

(St. Paul, Minn. 55101)

5-1. A Study of Cone Crop Stimulation in Minnesota Plantations. 122, 151.03. *Picea glauca, Pinus resinosa.*

Object: To determine means or techniques, especially in young stands, for developing and producing forest tree seed improved in quality, yield per tree, and ease of collection.

Methods: In 1962 staff members of the Division of Forestry, Minnesota Department of Conservation, selected several 20- to 25-year-old plantations that had reasonably good stocking. Out of these, one 1934 planting of red pine near Hibbing, Minn., and one 1939 planting of white spruce near Bemidji, Minn., were selected for treatment. Soil samples taken throughout each plantation were analyzed. Then replicated treatments were laid out in 1963 in each plantation to test the effects on cone production of thinning, discing (or other means of removing low vegetation competition), fertilizers, and topping of trees.

Accomplishments: Annual observations have been made of the treated plantations but no overall analysis of results is yet available. There has been cone production in the white spruce plantation but relatively little in the red pine plantation.

Cooperators: Lake States Forest Experiment Station.

Assignment: Emil Kukachka, Section Chief; Nathan Frame, District Forester; and Arthur Aamot, Assistant Area Forester of the Minnesota Department of Conservation; and Paul O. Rudolf, Principal Silviculturist, Lake States Forest Experiment Station.

6. Nekoosa-Edwards Paper Company
(Port Edwards, Wis. 54469)

6-1. Lake States White Spruce Seed Source Study. 111.1. *Picea glauca.* (4-5)

Object: To study local performance of geographic seed sources of white spruce as a guide in pulpwood planting programs.

Methods: Stock of 23 Lake States seed sources was planted in three replicate plantations at Minocqua, Wis. Not all sources occur in each replicate because of shortage of stock.

Accomplishments: Plots were established during 1956, 1957, and 1958 with 2-3 and 2-2 stock. First- and second-year survivals were recorded and first-year losses were replanted. First- and second-year heights have been tabulated. Height measurements scheduled for age 10 (from seed) could not be made and they probably will be read along with d.b.h. at age 15. Factors affecting height and vigor of the trees were recorded the first 3 years after planting. They will continue to be recorded periodically.

Assignment: B. L. Berklund, Forester.

6-2. Lake States Black Spruce Seed Source Study. 111.1. *Picea mariana.* (4-4)

Object: To study local performance of geographic seed sources of black spruce as a guide in pulpwood planting programs.

Methods: Stock from 24 Lake States sources was planted in three replicate plantations at Minocqua, Wis.

Accomplishment: Plots were established in 1956 and 1957 with 2-2 stock. Survivals were recorded the first and second years. First-year losses were replanted. Tree heights were measured the first, second, and fifth years after planting. Factors significantly affecting height and vigor were tabulated annually for the first 5 years after planting.

Assignment: B. L. Berklund, Forester.

6-3. Lake States Jack Pine Seed Source Study. 111.1. *Pinus banksiana.* (4-1)

Object: To study local performance of geographic seed sources of jack pine as a guide in pulpwood planting programs.

Methods: In the spring of 1954 2-0 stock from 25 Lake States seed sources was planted at Iron River and Nekoosa, Wis. Each area has three replicated plantations. Collections follow the subregions set up in the earlier Lake States red pine seed source study.

Accomplishments: At Nekoosa, heights were tabulated in 1958 and 1963 but have not been formally reported upon. In 1963 observations were limited to 25 trees per seed source, and d.b.h. was read for the first time. Because of their great influence on form and height development of young trees, data on insect, pathological, and weather damage have been tabulated annually through 1963 when these significantly affected main stem or vigor of data trees.

At Iron River, heights were tabulated in 1958, but not formally reported upon. Time was not available to read the scheduled 1963 heights and they, along with d.b.h. measurements, probably will be delayed until 1968. Data on damage affecting height and form were tabulated annually through 1960.

Assignment: B. L. Berklund, Forester.

6-4. Cooperative Regional Jack Pine Seed Source Study. 111.1. *Pinus banksiana.* (4-2)

Object, Methods: (See study 9-17 for details.)

Accomplishments: Made scheduled 1963 field observations on this study in the fall of 1963 and spring of 1964. (See study 9-17.)

Cooperators: Lake States Forest Experiment Station.

Assignment: B. L. Berklund, Forester.

6-5. Lake States Red Pine Seed Source Study. 111.1. *Pinus resinosa.* (4-3)

Object: To study local performance of geographic seed sources of red pine as a guide in pulpwood planting programs.

Methods: Stock from 25 Lake States seed sources was planted both at Minocqua and near Nekoosa, Wis. Each area has three replicate plantations. Collections follow the seven subregions set up in the earlier Lake States Forest Experiment Station red pine seed source study.

Accomplishments: Plots were established in 1956 with 2-2 stock. Survival and heights were recorded the first, second, and fifth years after planting. Factors affecting main stem or vigor, primarily disease and insect enemies, have been recorded annually through 1961. First-year losses were replanted.

Assignment: B. L. Berklund, Forester.

7. Quetico-Superior Wilderness Research Center[4]

(Ely, Minn. 55731)

7-1. Stimulation of Flowering. 111.0, 151.02, 112.02, 151.5. *Abies balsamea, Larix laricina, Picea abies, P. glauca, P. mariana, Pinus banksiana, P. cembra, P. griffithii, P. koraiensis, P. montana* var. *mughus, P. peuce, P. resinosa, P. strobus.* (5-3, 5-4)

Object: To determine the effects on flower production and growth of intra- and interspecific grafting, especially of pines.

Methods: Spring grafting by the side-slit method has been used in most cases. Standard bagging and pollination methods are used.

Accomplishments: (1) Grafting of conifers during 13 years has involved the use of the combinations shown in table I. One thousand compatible grafts are checked annually and are used in experimental work. (2) The number of cones produced by various graft combinations and clones has been recorded for 10 years. Cone production on this material has gradually increased during the 10-year period, although the severe June frost in 1964 caused damage to new growth and a sharp decrease in cone production. All combinations have produced some flowers, but generally the best results have been with white pine grafted on white pine. A systematic pattern of inter- and intraspecific pollination is being followed. (3) Records of male cone production have also been maintained from the same material for 10 years. A study of viability of pollen from different graft combinations was initiated in 1962. Since 1964, pollen has been dried and stored under vacuum at the Center. Efforts are being made to develop a method for maintaining a variety of kinds of pollen for use in the pollination work. (4) Pollinated cones are harvested at maturity, and cone size, seed yield, and seed size are recorded. Annual harvest of seed ranging from 2 to 3,900 per cross has been taken from the following controlled pollinations: white pine x white pine, white pine x Cembra pine, white pine x Korean pine, white pine x peuce pine, peuce pine x white pine, peuce pine x peuce pine, peuce pine x Cembra pine, Cembra pine x white pine, Cembra pine x Cembra pine, Korean pine x white pine, Korean pine x peuce pine.

Cooperators: University of Wisconsin, Department of Plant Pathology; University of Minnesota, School of Forestry.

Assignment: Clifford E. Ahlgren, Director.

TABLE I. — *Combinations used in grafting of conifers*

Scion species	Rootstock species									
	Pine					Balsam fir	Spruce			Tamarack
	Red	Eastern white	Jack	Scotch	Mugho		White	Black	Norway	
Tamarack	X	X				X	X	X	X	
Spruce:										
Black							X	X	X	
White							X	X	X	
Norway							X	X	X	X
Pine:										
Eastern white	X	X	X	X	X	X				
Red	X	X								
Peuce	X	X				X				
Korean	X	X	X	X	X	X				
Himalayan	X	X	X	X	X	X				
Cembra	X	X	X	X	X	X				

7-2. Development of Blister Rust Resistance in White Pine. 151.5. *Pinus strobus, P. peuce.* (5-5, 5-6, 5-7, 5-8)

Object: To develop strains of eastern white pine phenologically suited to northern Minnesota, and which have sufficient resistance to white pine blister rust to be of practical use. (See study 12-5.)

Methods: Blister rust test areas are being maintained where incidence of rust is very high and the trees that are under test are exposed to heavy natural inoculum. Additional *Ribes* bushes were

[4] *In 1964 the Hill Family Foundation awarded a grant to the University of Minnesota to assist in the continuation of the Center's tree improvement work. The projects listed are partially supported by this grant.*

planted in the areas to help maintain uniform inoculation. Other methods of inoculaton are used as described under accomplishments. All areas are fenced to exclude deer.

Accomplishments: (1) Stratified seed from interspecific and intra-specific crosses is planted in the nursery and grown for two seasons prior to inoculation. In August, humidity within the frames is increased with wet burlap and the 2-year-old seedlings are inoculated, using infected *Ribes* leaves of the native species. Degree of infection is recorded after needle lesions develop the next spring. Stem cankers and aecia appear the following spring. Observations in 1964 on seedlings inoculated the previous year indicated from 0 to 45 percent rust-free seedlings in eastern white pine. In *Pinus peuce* 83 percent of the seedlings were rust-free or had less than 5 percent of the crown infected, while in eastern white pine from 44 to 100 percent of the seedlings were in these two categories.

(2) In 1958 some 210 root grafts were made in the Center's blister rust test area, using scions from seven rust-free selections growing near Grand Marais, Minn. At the same time 90 grafts were made, using scions from the native pine on the plantation at the Center. Root grafts were also made by Drs. Riker and Patton of the University of Wisconsin and were set out in 1949 and 1954. Infection ranged from 13 to 38 percent on the grafts, the lowest being on two selections from Grand Marais. Infection rate of ungrafted seedlings transplanted into the area is 64 percent.

(3) Five hundred hybrid seedlings obtained from the University of Wisconsin in 1955 have been examined annually for infection. These seedlings were derived from 10 crosses of parent trees showing certain degrees of resistance. Disease has appeared on seedlings from all 10 crosses and ranges from 96 to 100 percent. Since these crosses are very susceptible to rust, they will not be tested further.

(4) In 1955 and 1957 seedlings of Basswood Lake selections were planted in the hybrid seedling test area. Growth, infection, and survival records have been maintained. Infection ranges from 86 to 100 percent.

(5) A successful technique for bark inoculation, developed at the Center and described previously, is being used to inoculate selections showing the highest percentage of rust-free grafts. Some inoculations were made in 1965, and others are planned when seedlings become large enough for the test.

Cooperators: University of Wisconsin, Department of Plant Pathology.

Assignment: Clifford E. Ahlgren, Director.

8. U. S. Forest Service, Forest Products Laboratory

(Madison, Wis. 53705)

8-1. Wood Quality Evaluations for Genetics. 151.32. General. (7-1)

Object: To provide overall evaluations of density and fiber characteristics in wide samplings such as Forest Surveys to assist in determining individual tree variations and outstanding or superior wood quality.

Methods: Specific gravity, summerwood percentages, and fiber characteristics were determined in cooperation with genetics and silvicultural studies at the Forest Experiment Stations.

Accomplishments: For the initial study (the Southern Wood Density Survey, begun in 1956), mass-sampled specific gravity determinations of the predominant southern yellow pines have been completed for Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, and North Carolina. In 1960, the Western Wood Density Survey was initiated in all commercial forest areas west of the Great Plains. Status reports for both the Southern and Western Surveys were prepared as U.S. Forest Service Research Papers FPL-26 and FPL-27. Other publications are as follows:

Mitchell, Harold L. Development of an adequate concept of wood quality for guidance of geneticists and forest managers. Fifth World Forestry Congress. 1960.

Mitchell, Harold L. A concept of intrinsic wood quality and non-destructive methods of determining quality in standing timber. FPL Report No. 2233. Oct. 1961.

Taras, Michael A., and Wahlgren, Harold E. A comparison of increment core sampling methods for estimating tree specific gravity. U.S. Forest Serv. Res. Paper SE-7. Dec. 1963.

Mitchell, Harold L. Patterns of variation in specific gravity of southern pines and other coniferous species. TAPPI 47 (5), May, 1964, and also Soc. Amer. Foresters Proc., Denver, Colo. 1964.

Christopher, Joe F., and Wahlgren, Harold E. Estimating specific gravity of south Arkansas pine. U.S. Forest Serv. Res. Paper SO-14. 1964.

Cooperators: Southern, Southeastern, Intermountain, Pacific Northwest, and Pacific Southwest Forest Experiment Stations and contiguous National Forests.

Assignment: H. E. Wahlgren, L. E. Lassen, and D. Pronin, Technologists.

8-2. Wood Density of Red Pine from Geographic-Climatic Seed Sources. 151.321, 111.1. *Pinus resinosa.* (7-2)

Object: To determine the variations in increment core specific gravity within and between seed sources as a possible indicator of wood quality related to seed source variations.

Methods: All the trees from each of 50 seed sources present on each of 8 plots were sampled by randomly oriented increment cores. Estimates will be made of the dry mass of wood from the increment core specific gravity and the volume of a nominal pulpwood bolt at the breast height diameter. The analysis will include the effects of height and diameter growth and summerwood percentages in seeking differences among the 50 seed sources replicated on 8 plots.

Accomplishments: Analyses of variations in mean specific gravity values for the 50 respective seed sources showed a wide range (0.304-0.341), while the 9 geographical-climatic regions showed a smaller range (0.316-0.329).

The Northeastern States regional mean differed significantly from any of the eight Lake States regional means at the 1-percent level by Duncan's multiple range test. Within those nine geographical-climatic regions, only three regions showed significant differences among the respective seed sources. These data are now included in a limited-distribution report prepared by T. A. Peterson, "Variation in Specific Gravity of Different Red Pine Seed Sources at Kane, Pennsylvania."

In 1964 a re-evaluation was initiated through new sampling by seed sources shown by the original study to reflect relatively high or low potential wood quality. This study will evaluate the relationships of specific gravity as a criterion of wood quality to anatomical features of the wood and external characteristics of the wood.

Cooperators: Northeastern Forest Experiment Station and the University of Wisconsin.

Assignment: M. Y. Pillow, Technologist, and T. A. Peterson, Research Associate.

8-3. Evaluation of Wood Characteristics of White Ash from Different Seed Sources. 251.32, 211.1. *Fraxinus americana.* (7-3)

Object: To determine specific gravity, dry mass of wood, and fiber characteristics, particularly fibril angles, as indications of geographic or ecotypic variations.

Methods: Selected seed sources of white ash saplings outplanted at the Morris Arboretum, Philadelphia, Pa., have been sampled. Specific gravity and dry mass were determined for the first 6 or 8 years' height growth. Fibril angles and fiber lengths will be determined on the 1957 and 1958 years' radial growth in the 1956 height growth.

Accomplishments: Preliminary analyses of variations in specific gravity of the wood showed no clear trends between the seed sources, although variations in site conditions appeared associated with the variability in density as a criterion of wood quality. This study will be completed by fiber length measurements now in progress for particular seed sources completely replicated on each of the three sites.

Cooperators: Northeastern Forest Experiment Station.

Assignment: M. Y. Pillow, L. E. Lassen, and Charlotte Hiller, Technologists.

8-4. Wood Quality of Superior Hybrid Poplar Clones. 251.32, 211.3. *Populus* spp. (7-4)

Object: To determine density and tension wood occurrences in selected clones of hybrid poplars being tested in the Northeastern States.

Methods: Samplings are made by 1-foot cross-sections at breast height of thinned trees to determine specific gravity and dry mass of wood in a nominal pulpwood bolt from the butts of the trees from 10 selected clones planted at Beltsville, Md., and Hopkins, Mass. The samplings are made during the periodic thinnings of 100 tree plantations, after which the 13 crop trees will be evaluated by increment core samples.

Accomplishments: The sampling of selected clones by the Northeastern Station and determinations of specific gravity and occurrences of tension wood have been completed. Analyses of variability within and between clonal samples are now in progress.

Cooperators: Northeastern Forest Experiment Station.

Assignments: M. Y. Pillow and D. Pronin, Technologists.

8-5. Tension Wood Formation in Bent Hybrid Poplars. 251.32, 211.3. *Populus* spp. (7-6)

Object: To determine whether there are significant differences in the occurrences of the gelatinous fibers of tension wood among selected clones of hybrid poplars.

Methods: Three saplings from each of 10 clones will be bent to a maximum of about 12 degrees from the vertical and held in that position for 3 years. Since the amount of bending will be continuously variable, examinations will determine the occurrences of gelatinous fibers before and after bending in at least three positions between 1 and 6 feet above the ground.

Accomplishments: The best trees were grown for 4 years and shipped to Madison for sample processing. Occurrences of the aberrant gelatinous fibers characteristic of tension wood are being determined for successive heights in the trees both above and below the points of maximum deviation from a vertical position in the trunks.

Cooperator: Northeastern Forest Experiment Station.

Assignment: M. Y. Pillow, and D. W. Lewis, Technologists.

9. U. S. Forest Service, Lake States Forest Experiment Station

(St. Paul Campus, University of Minnesota, St. Paul, Minn. 55101)

9-1. The Botanical and Commercial Ranges of Forest Tree Species in the Lake States. 111, 151.4. *Abies balsamea, Picea glauca, P. mariana, Pinus banksiana, P. resinosa, P. strobus.*

Object: To accumulate and publish accurate and detailed information on the natural distribution and commercial ranges of important forest tree species in the Lake States.

Methods: Information is assembled from herbarium records, seed collection records, Forest Survey field plot data, Forest Survey reports, and comparable sources. Preliminary maps and reports are checked by local foresters in the field. Results then are published and include maps showing the distribution limits, counties with volumes of 1,000 cords or more, and actual collection locations of herbarium samples and comparable identifiable material.

Accomplishments: Three species reports have been published as follows:

Rudolf, Paul O. and R. E. Schoenike. 1963. Botanical and commercial range of jack pine in the Lake States. U.S. Forest Serv. Res. Note LS-15, 4 pp. Lake States Forest Expt. Sta., St. Paul, Minn.

———— and John W. Andresen. 1965. Botanical and commercial range of red pine in the Lake States. U.S. Forest Serv. Res. Note LS-62, 4 pp. Lake States Forest Expt. Sta., St. Paul, Minn.

———— and ————. 1965. Botanical and commercial range of eastern white pine in the Lake States. U.S. Forest Serv. Res. Note LS-63, 4 pp. Lake States Forest Expt. Sta., St. Paul, Minn.

Similar Notes are in preparation for white spruce, black spruce, and balsam fir.

Cooperators: Cranbrook Institute of Science; Michigan State University; Michigan Technological University; Milwaukee Public Museum; Universities of Michigan, Minnesota, and Wisconsin; Conservation Departments of Michigan, Minnesota, and Wisconsin; and the National Forests in the Lake States.

Assignment: Paul O. Rudolf, Principal Silviculturist.

9-2. Denbigh Plantations. 111.0, 211.0. General. (8-1)

Object: To test the feasibility of forest planting in the sandhills of McHenry County, N. Dak.

Methods: Between 1931 and 1942, stock of some 40 tree species of known seed origins was planted on 270 acres of sandhill area, using different methods of ground preparation and different intensities of aftercare. Periodic observations have been made on survival and development.

Accomplishments: The most promising species appear to be *Pinus ponderosa, Juniperus virginiana, J. scopulorum, Pinus banksiana, P. sylvestris, Larix sibirica, Picea pungens,* and *P. glauca* among the conifers and *Populus deltoides, Fraxinus pennsylvanica, Acer negundo, Quercus macrocarpa,* and *Ulmus pumila* among the deciduous species. Thorough ground preparation and annual cultivation for at least 5 years are necessary for successful establishment.

Also, an analysis of height growth, d.b.h., crown form, branch habit and foliage density of ponderosa pine from eight seed sources indicates that trees produced from eastern Montana seed sources are better adapted than the Black Hills, S. Dak., seed sources more frequently used for planting programs in the Northern Plains.

Cooperators: North Dakota State School of Forestry.

Assignment: David H. Dawson, Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-3. Spruce Species and Seed Source Study. 111.0, 111.1. *Picea abies, P. glauca, P. glehni, P. mariana, P. obovata, P. omorika, P. orientalis,* and *P. rubens.* (8-2)

Object: To study the development of spruce of several species and seed sources in northeastern Wisconsin and to assemble breeding material of known origin.

Methods: White spruce of seven seed origins, Norway spruce of six seed sources, red spruce of two seed sources, and one source each of Sakhalin, Siberian, Oriental, Serbian, and black spruces were grown in the nursery at Rhinelander, Wis., and field-planted in five localities in the northern Lake States in the spring of 1936. The severe drought of 1936 eliminated all but the block in northeastern Wisconsin. Periodic observations of survival and development have been made upon it.

Accomplishments: A report on 16-year and 29-year measurements is being prepared. Seed sources from southeastern Ontario are superior to native northeastern Wisconsin seed sources.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; James P. King, Associate Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-4. A Seed Source Test of Eastern Redcedar in the Denbigh Experimental Forest. 111.1. *Juniperus virginiana.*

Object: To locate and identify well-adapted seed sources of eastern redcedar for shelterbelt usage in the Northern Prairie Plains, and to assemble material which could be used in breeding programs.

Methods: Seedlings from 12 seed sources extending as far south as Oklahoma and as far north as western Minnesota were assembled and planted in the Denbigh Experimental Forest in May 1964 in a replicated block planting. Plants were grown

by the Central States Forest Experiment Station at George White Nursery in Missouri, and several private and state nurseries in the Plains. Measurements will be made at the end of 2, 5, 10, and 20 years for height, d.b.h., crown spread, winter desiccation, and variations in resistance to physiogenic and pathogenic diseases and to insect attacks.

Accomplishments: Sources from West Virginia and Arkansas have suffered severe winter killing compared with the more northern sources.

Cooperators: Central States Forest Experiment Station; North Dakota School of Forestry.

Assignment: David H. Dawson, Plant Geneticist.

9-5. Variation in Seedling Radiosensitivity Between Northern Forest Tree Species, and Between Seed Origins Within Species. 111.1, 112.11, 211.1, 212.11. *Betula alleghaniensis, Juniperus virginiana, Larix laricina, Picea abies, P. glauca, Pinus banksiana, P. resinosa, P. strobus, Thuja occidentalis.*

Object: To determine the relative sensitivity of northern forest tree species and provenances within species to various levels of chronic and acute gamma radiation and to determine the factors responsible for the differential radiosensitivity.

Methods: Fifteen origins of white spruce, 12 origins of eastern redcedar, and 23 of jack pine are planted in replicated arc plots at various low-level dose rates in the gamma radiation field. Also included are single origins of red pine, white pine, and Norway spruce. A number of seed origins of yellow birch, eastern larch, and northern white-cedar are presently in the nursery and will be planted in the radiation field in the next 2 years. Development of shoots and foliage in the various chronic radiation levels is observed and measured throughout the growing season. Samples for microscopic study of plant development are collected at regular intervals during the growing season. In the jack pine, the effect of the various chronic radiation dose rates on flowering is evaluated, and seeds collected from these trees are studied. Acute gamma irradiation effects are studied on very young seedlings in a self-contained gamma irradiator.

Accomplishments: Collection of data is underway.

Assignment: Thomas D. Rudolph, Plant Geneticist; Hans Nienstaedt, Principal Plant Geneticist.

9-6. European Larch Seed Source Test. 111.1, 111.0. *Larix decidua, L. laricina, L. leptolepis, L. sibirica.* (8-4)

Object: To determine the variation between European larches of several known seed origins and to assemble breeding material of those origins.

Methods: European larch seed of 11 origins, and 1 origin each of Siberian and Japanese larches were received from the International Union of Forest Research Organizations in 1945 and were sown in the Eveleth Nursery in Minnesota in May 1946. In the spring of 1949 trees of each lot were field-planted in north-central Minnesota, northeastern Wisconsin, and central Lower Michigan. Periodic observations of growth and development have been made.

Accomplishments: Source-related differences were noted after 5 years in the field, with some European larches making better growth but a little poorer survival than native tamarack planted as a comparator in northern Minnesota and Wisconsin. Survival in general has not been very high; most of the mortality occurred the first year. The northeastern Wisconsin plot was sprayed with malathion in 1962 to control larch sawfly. Examination of the plantation in 1962 revealed that the height and diameter growth of European larch appears superior to that of native tamarack. Survival of European larch was as good as or better than that of tamarack in all but one plot. The Wisconsin planting was examined twice in 1963 to determine if differences in larch sawfly damage existed between seed sources. None of the seed sources indicated anything but very light damage.

Cooperators: International Union of Forest Research Organizations.

Assignment: J. P. King, Associate Plant Geneticist; Hans Nienstaedt, Principal Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-7. Seed Source Test of Siberian, Dahurian, and Sukachev larch in the Denbigh Plantations. 111.1, 111.0, 112.01. *Larix gmelini, L. sibirica,* and natural hybrid *Larix.*

Object: To determine which of the six sources of *Larix* being tested will be best suited for planting in the North Dakota area.

Methods: Seed was received from Russia in 1956 and seeded at Rhinelander, Wis. It was shipped as 2-2 transplants to Bottineau, N. Dak., in 1961, where it was field planted in a 4-tree, 10-replication planting in the Denbigh Experimental Forest. Measurements of height, d.b.h., and resistance to physiological and pathogenic diseases and to insect damage will be made at 2, 5, 10, and 20 years.

Accomplishments: Measurements and observations to date indicate that the sources of *L. sibirica* from two of the areas (the Altai Mountains Autonomous Province and the Tuvinskaya Autonomous Province) have much higher rates of survival and growth than the other sources of *L. sibirica, L. gmelini* or the hybrid.

Cooperators: North Dakota State School of Forestry.

Assignment: David H. Dawson, Plant Geneticist.

9-8. A Rangewide Study of Seed Source Variation in Tamarack. 111.1. *Larix laricina.*

Object: To determine the kind and amount of variation in the species over its range; to compare and evaluate the genotypic variation with similar patterns of variation found in other transcontinental species; and to add to our knowledge and understanding of the evolutionary and migratory

history of the wide-ranging northern tree species. (See study 11-5.)

Methods: The School of Forestry of the University of Minnesota initiated a study of tamarack with seed collections in 1960-61 and 1962. The Lake States Forest Experiment Station received 55 seed collections from the University in 1963. Ten collections were made by the Station, and an additional 26 collections were received from the University of Minnesota in 1964, 6 of which represented areas previously sampled in 1960-62. After 2 years in the seedbed and 1 year in the transplant bed the seedlings will be outplanted in 4-tree plots with 10 replications in a randomized complete block design. Data will be collected in the nursery phase of the study with emphasis on germination, survival, height growth, foliage color, and phenology. Needles will also be collected for laboratory examination. In the field, data will be taken on survival and height growth with detailed observation and measurement every 5 years.

Accomplishments: Seed was sown in the nursery in 1963, and germination was very poor. Only eight sources had sufficient seedlings to carry over. Seed collected in 1964 was sown in 1965. Germination improved over 1963 sowings.

Cooperators: School of Forestry, University of Minnesota; Nicolet National Forest.

Assignment: R. B. Hill, Assistant Plant Geneticist.

9-9. International Union Source of Seed Study. 111.1. *Picea abies, Pinus sylvestris.* (8-14)

Object: To explore the variation in Scotch pine and Norway spruce of several origins when planted in the Lake States and to accumulate breeding material of known origin.

Methods: Scotch pine and Norway spruce seed were collected from stands throughout Europe by the International Union of Forest Research Organizations in the late 1930's. From this, 10 lots of Scotch pine and 14 lots of Norway spruce were sown in the Cass Lake, Minn., Nursery in 1938. Field plantings of this stock were made in the spring of 1941 in north-central Minnesota and west-central Lower Michigan. Observations on growth and survival have been made periodically.

Accomplishments: In Lower Michigan, 15 years after planting, differences between sources in survival and development were evident. Some sources from Poland seemed best for both species on the basis of survival and height development combined. Some results have been reported as follows:

Slabaugh, Paul E., and Paul O. Rudolf. 1957. The influence of seed source on the development of Scotch pine and Norway spruce planted in Lower Michigan (15-year results). Mich. Acad. Sci., Arts, & Letters Papers (1956) 42: 41-52, illus.

Rudolf, Paul O., and Paul E. Slabaugh. 1958. Growth and development of 10 seed sources of Scotch pine in Lower Michigan (15-year results). U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 536, 2 pp.

_____ and _____. 1958. Growth and development of 12 seed sources of Norway spruce in Lower Michigan (15-year results). U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 537, 2 pp.

Cooperators: International Union of Forest Research Organizations.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-10. A Seed Source Test of Norway Spruce and Siberian Spruce. 111.0, 111.1. *Picea abies* and *P. obovata.*

Object: To determine which seed sources of *Picea abies* and *P. obovata* will be best suited for planting in the North Dakota area.

Methods: Seed from 11 locations in Russia between 62° 45′ N. latitude and 53° 45′ N. latitude, and between 20° E. longitude and 65° 30′ E. longitude, was received in 1956. Some of the sources were grown at Petawawa Experiment Station, Chalk River, Ontario, and some at Rhinelander, Wis. In 1962 the 2-2 stock was planted on the Denbigh Experimental Forest in North Dakota and at the Pike Bay Experimental Forest in Minnesota. Measurements are being made the second, fifth, and tenth years after planting and include height, d.b.h., and disease and insect resistance factors.

Accomplishments: The *P. abies* in this planting is showing considerably more adaptability to the climate than earlier trials of *P. abies* from Central European origins. There has been less late spring frost damage to buds of the Norway spruce than to those of several sources of white spruce in the area.

Cooperators: North Dakota School of Forestry.

Assignment: David H. Dawson, Plant Geneticist.

9-11. Seed Source Study of Engelmann Spruce. 111.1, 112.0. *Picea engelmannii.*

Object: (1) To assemble a range of Engelmann spruce material for studies of interspecific hybridization; (2) to study the pattern of genetic variation in Engelmann spruce.

Methods: Seed obtained from about 30 locations throughout the natural range of Engelmann spruce has been sown in the nursery. Seedlings will be grown to 3-0 stock and then planted in permanent field plantings. Both nursery and field plantings will follow the randomized complete block design. The seed sources will be checked periodically for differences in morphology, growth rate, survival, and insect-disease incidence. When the Engelmann spruce reaches flowering age, detailed plans for hybridization with white spruce will be developed.

Accomplishments: Seed was sown at the Hugo Sauer Nursery, Rhinelander, Wis., in the spring of 1965.

Cooperators: Regions 1, 2, 3, 4, and 6 of the U.S. Forest Service have collected seed. The British Columbia Forest Service has furnished 15 seed lots. Field plantings will be established on National Forests in Region 9 and cooperative plantings in Region 3 if sufficient seedlings are available.

Assignment: James P. King, Associate Plant Geneticist.

9-12. Ecotypic Variation in White Spruce Growing in Zones With Different Lengths of Growing Season in the Upper Peninsula, Michigan. 111.1. *Picea glauca.* (8-7)

Object: To determine (1) whether distinct white spruce ecotypes have evolved as a result of climatic diversity in the central Upper Peninsula, (2) the relative dry-matter production efficiency of long- and short-growing season seed sources, and (3) the relative importance of photoperiod and temperature in determining the length of the growth period.

Methods: White spruce stands in the central Upper Peninsula of Michigan were selected in zones with about 80-, 110-, and 140-day growing seasons. Seeds were collected from three stands in each zone, and seedlings have been grown in the greenhouse under controlled temperatures and daylengths. If these tests indicate ecotypic differences, field progeny tests will be made and phenological observations will be carried out on the parent stands.

Accomplishments: Greenhouse studies under controlled conditions have been conducted for 2 years; a nursery test was established in the spring of 1959. Field plots were established in 1963.

Cooperators: Michigan Technological University.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-13. A Study of Racial Variation in White Spruce. 111.1. *Picea glauca.* (8-8)

Object: (1) To develop a sound basis for intraspecific hybridization of white spruce through the study of morphological and physiological variation throughout the range of the species; (2) to determine correlation between juvenile and mature growth of the trees; and (3) to collect a diversity of germ plasm for improvement work.

Methods: White spruce seed from 29 localities over the botanical range were collected and are growing in the nursery. They will be outplanted as 2-2 stock in at least four localities in the Lake States. Observations will be made in the nursery and in the field to determine any differences in growth, survival, development, and reaction to injurious agencies that may be associated with origin.

Accomplishments: Part of each seed lot was sown in the Hugo Sauer Nursery in northeastern Wisconsin in the spring of 1958, and observations have been made on germination and height growth above the cotyledons. Vigor and taxonomic characteristics were scored on 1-0, 2-0, and 2-2 stock. The results are now being analyzed and prepared for publication. Field plots were established in 1962 throughout the Lake States and in Saskatchewan, Ontario, New Brunswick, Maine, and Maryland.

Cooperators: Petawawa Forest Experiment Station; Bureau of Land Management (Alaska); Northeastern Forest Experiment Station; Manitoba Forest Service; University of Minnesota, School of Forestry; University of Maryland, Natural Resources Institute; Michigan State University, Department of Forestry; Michigan Technological University; Acadia Forest Experiment Station, Fredericton, New Brunswick; Forest Nursery Station, Indian Head, Saskatchewan.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-14. White Spruce Racial Variation Test, Toumey Nursery. 111.1. *Picea glauca.* (8-6)

Object: To supplement the rangewide seed source study by determining the occurrence of morphological and physiological races in the white spruce of several Ontario and Quebec sources.

Methods: White spruce seedling stock from 19 Ontario and Quebec origins was obtained from the Petawawa Forest Experiment Station in May 1956 and transplanted in the nursery at Rhinelander, Wis. In the spring of 1958, the transplants were set out in two randomized blocks adjacent to the Toumey Nursery near Watersmeet, Mich. Because of nursery expansion, the plantation was moved to another locality near Watersmeet in the fall of 1962. Growth and development have been observed periodically.

Accomplishments: Field plots were established in 1958 and re-established in 1962.

Cooperators: Petawawa Forest Experiment Station; Ottawa National Forest.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-15. Seed Source Study of Blue Spruce in North Dakota. 111.1. *Picea pungens.* (8-5)

Object: To test blue spruce of several known origins in Northern Plains shelterbelts.

Methods: Blue spruce transplants of seven origins, ranging from Arizona to northern Wyoming, were planted in two North Dakota shelterbelts in 1960. The stock was received from the University of Minnesota. The trees were planted in rows between a row of deciduous trees and a row of shrubs. The trees will be cultivated for 5 years. They will be examined after 1, 2, 5, 10, 15, and 20 years in the field for survival, growth, crown development, and foliage color.

Accomplishments: Stock was obtained from the Cloquet Nursery of the University of Minnesota and transplanted in the Hugo Sauer State Nursery at Rhinelander Wis.

Cooperators: University of Minnesota, School of Forestry; North Dakota State Forester.

Assignment: David H. Dawson, Plant Geneticist.

9-16. Testing Red Spruce Seed Sources. 111.1. *Picea rubens.*

Object: (1) To obtain red spruce parent stock adapted to the climatic conditions in the Lake States and suitable as parents for interspecific hybridization in the genus *Picea*, (2) to obtain information on racial variation and on the modificational plasticity of the species.

Methods: A 2-tree-plot test of 15 seed sources of red spruce replicated 25 times in random blocks.

Accomplishments: Field planting was established in 1961.

Cooperators: Canada Department of Forestry, Forest Research Branch, Fredericton, New Brunswick; Nicolet National Forest.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-17. Regional Jack Pine Seed Source Study in the Lake States. 111.1. *Pinus banksiana.* (Planned jointly with the University of Minnesota School of Forestry.) (8-9)

Object: To determine whether (1) there are important and heritable racial differences in jack pine within the Lake States, (2) local, native seed sources are generally best, and (3) there are superior seed sources that may be better than local sources in some localities.

Methods: In 29 localities in the Lake States seed was collected from good stands of jack pine in 1951-52; stock was grown in State nurseries in Wisconsin and Minnesota and field-planted as 2-0 seedlings in the spring of 1954 in 17 localities in the 3 states. Fail spots were replanted in 1955. Examinations were made at the end of the first, second, fifth, and tenth growing seasons in the field. Special examinations were made on some plantations during intervening years.

Accomplishments: Fifth-year examinations are beginning to show some origin-associated differences in growth, insect damage, and disease susceptibility. Ten-year measurements in 1963 revealed differences between seed sources in height and d.b.h. at almost every plantation. Seed source differences in some plantations were noted in forking, ramicorn branching, and incidence of white-pine weevil, jack-pine shoot borer, pitch nodule maker, and oak-pine gall rust. Some sources made as much as 25 percent greater height growth than the local stock. Some results are reported in:

King, J. P., and Hans Nienstaedt. Variation in needlecast susceptibility among 29 jack pine seed sources. Silvae Genetica. In press.

Cooperators: Universities of Minnesota and Michigan; Conservation Departments of Minnesota, Wisconsin, and Michigan; National Forests of the Lake States; Nekoosa-Edwards Paper Co.; Mosinee Paper Mills Co.; Burnett and Marinette Counties, Wis.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; James P. King, Associate Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-18. Nursery Study of Range-wide Seed Source Variation in Jack Pine. 111.1. *Pinus banksiana.*

Object: To determine the patterns of variation in jack pine over its entire distribution and to increase our knowledge and understanding of the evolution and migration histories of jack pine.

Methods: Ninety-two seed collections of jack pine covering the entire range of the species will be studied in 10-tree plots with 5 replications. The study has been established at the Hugo Sauer Nursery and will be maintained there for 5 years. An intensive scoring of morphological, qualitative, growth, and phenological characteristics will be undertaken in the nursery.

Accomplishments: The study was planted in the nursery in 1962. Measurements have revealed striking differences in height growth and height growth patterns, fall coloration, stem color, earliness of flowering, and other characteristics. The study was field planted in the spring of 1965.

Cooperators: Seed collections used in the study were supplied by the Petawawa Forest Experiment Station, Chalk River, Ontario.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; James P. King, Associate Plant Geneticist.

9-19. Lammas Growth and Prolepsis in Jack Pine. 111.1, 111.3, 151.0, 151.3. *Pinus banksiana.* (8-10)

Object: To determine the characteristics of lammas growth and prolepsis in jack pine, the variation in frequency of occurrence of these phenomena over the range of the species in the Lake States, their effects on height and diameter growth and tree form, and possible factors influencing their occurrence in certain areas and in individual trees.

Methods: Growth periodicity and total height growth of 300 trees with various height growth habits were studied by taking weekly height growth measurements in plantings with seed origins representing the distribution of jack pine in the Lake States. Racial and individual tree variation in incidence of lammas growth and prolepsis in 29 sources growing at 6 different locations and in 4 natural stands were determined from individual tree observation made over 3 successive growing seasons. The effect of an extended photoperiod on the incidence of these phenomena was observed in two 96-tree plots of 4-year-old trees at the North Central School and Experiment Station at Grand Rapids, Minn. One plot was illuminated to simulate the longer daylength prevailing at 58° N. latitude; the other served as a control. Within-plot

comparisons of weekly growth measurements on trees with and without lammas growth and prolepsis were made.

Differences in the anatomy and morphology of buds and stem tissues between trees with lammas growth and prolepsis and those with normal growth were studied microscopically in sections cut from samples taken, in the winter condition, from trees with various types of growth. The relations of lammas growth and prolepsis to diameter growth and possible false ring formation were microscopically studied on the same material.

Accomplishments: The measurements indicate that the frequency of occurrence of lammas growth, prolepsis, and combinations of both varied between the seed sources, and suggest that the tendency to form these shoots is under genetic control. The variation patterns between sources in the occurrence of late shoots was clinal or continuous indicating that formation of lammas and proleptic shoots is controlled by more than a single pair of genes, or that there is a gradual change in frequency of one or a few genes in the population sampled in the study.

Extension of the photoperiod caused a marked increase in the frequency of lammas and proleptic shoot formation. Trees with lammas growth had a longer height growth period than those with normal growth; their growth period was further extended by long-day conditions, and they showed a different seasonal growth pattern as well as greater annual height growth than normal trees.

Lammas growth and prolepsis did not result in detectable false rings. Deviations from normal shoot development and tree form resulting from lammas growth and prolepsis depended upon the type of late shoot and on its magnitude. Some accomplishments are reported in:

Rudolph, T. D. 1961. Lammas growth and prolepsis in jack pine in the Lake States. Ph.D. Thesis, University of Minnesota, 325 pp. Univ. Microfilms, Ann Arbor, Mich. (Dissertation Abstr. 22(7): 2156-2157.)

———————. 1964. Lammas growth and prolepsis in jack pine in the Lake States. Forest Science Monograph 6. 70 pp.

Cooperators: School of Forestry, University of Minnesota.

Assignment: Thomas D. Rudolph, Plant Geneticist.

9-20. White Pine Blister Rust Race Study. 111.1, 151.5. *Pinus flexilis, P. koraiensis, P. peuce, P. strobus, Ribes* spp. (8-3)

Object: To determine whether there are races of white pine blister rust that vary in pathogenicity on pine. If such races are found, then an attempt will be made to identify these races as to infection pattern, host reaction, distribution, and relative abundance.

Methods: Aeciospore collections from throughout the range of white pine are sent to St. Paul and tested for evidence of variability on the ribes host. Material which exhibits racial differences on ribes is then tested on pine differentials. Tests on pine are limited to those collections which show promise on ribes because of the inherent difficulties involved in working with the pine host.

Accomplishments: Controlled environment chambers have been acquired that will eliminate the influence of temperature and humidity on test results much more effectively than was true with facilities (special greenhouse chambers) previously used. Techniques have been developed for transferring single sporidia to pine needles in a viable condition, but so far no infection has been obtained by this method. No evidence has yet been found of races on the pine host. The work on pines has been very limited due to the meager evidence for differences on the ribes host. Currently, methods used are being evaluated to determine whether a fresh approach might be more effective.

Cooperators: University of Minnesota, Plant Pathology Department; U.S. Forest Service, Pest Control Personnel.

Assignment: Ralph L. Anderson, Principal Plant Pathologist; Darroll D. Skilling, Associate Plant Pathologist.

9-21. Ponderosa Pine for the Great Plains Region (A Study of the Adaptability of Provenances from the Eastern Portion of Its Native Range). 111.1, 151.07. *Pinus ponderosa.*

Object: (1) To find the ponderosa pine seed source or seed sources best adapted for shelterbelt use in the different regions of the Great Plains, (2) to determine the range and distribution pattern in drought resistance, winter hardiness, and other characters of silvical and morphological importance, and to interpret these patterns in terms of the evolution of the species and their implication with regard to the improvement of the species, and (3) to provide material and data for progeny tests, within-stand variation studies, and hybridization research.

Methods: Seed was collected in 1962, 1963, and 1964 from 80 locations in the eastern portions of the range of ponderosa pine. Specific locations were chosen mainly on the basis of having a climate closely resembling that of the Plains, with emphasis on effective precipitation. The seed was planted in the Towner Nursery at Towner, N. Dak., the Bessey Nursery at Halsey, Neb., and the Forest Nursery Station at Indian Head, Saskatchewan, in the spring of 1965. The nursery phase of the study, lasting 3 years, involves seedling variation between sources for such traits as germination, number of cotyledons, color of hypocotyl, length and width of primary needles, serration of primary needles, occurrence of bloom on primary needles, winter injury, phenological characteristics, root development and height growth, and caliper measurements. The field plantings will be

made in North Dakota, South Dakota, Minnesota, Saskatchewan, Nebraska, and Kansas, as well as several other North-Central States. Plantings will be measured the second, fifth, tenth and twentieth years for height, d.b.h., crown spread, foliage characteristics, winter desiccation, and disease and insect resistance factors.

Cooperators: Rocky Mountain Forest and Range Experiment Station; North Dakota School of Forestry; Forest Nursery Station, Indian Head, Saskatchewan; and NC-51 Cooperators from Nebraska, South Dakota, Minnesota, Wisconsin, Michigan, Missouri, Iowa, Oklahoma, and Kansas.

Assignment: David H. Dawson, Plant Geneticist, and Hans Nienstaedt, Principal Plant Geneticist, Lake States Forest Experiment Station; and Ralph Read, Principal Silviculturist, Rocky Mountain Forest and Range Experiment Station.

9-22. A Study of Root Growth in Ponderosa Pine. 111.1, 151.0, 151.3. *Pinus ponderosa.*

Object: To evaluate seed source variation in ponderosa pine root growth and development. In addition, effects of different combinations of photoperiod and temperature on root growth will be tested.

Methods: Twelve seed sources will be germinated and transplanted to glass tubes housed in light-tight boxes.

Accomplishments: Study initiated in 1963.

Assignment: Robert B. Hill, Assistant Plant Geneticist.

9-23. Red Pine Seed Source Study, Plot 99. 111.1. *Pinus resinosa.* (8-11)

Object: To explore racial variation in red pine from the Lake States.

Methods: Transplant (2-1) stock grown from red pine seed of 48 Lake States and 3 northeastern United States sources was field-planted on the Pike Bay Experimental Forest (north-central Minnesota) in the spring of 1937. (Replicates of most lots were planted at the same time by the Northeastern Station on the Kane Experimental Forest in Pennsylvania.) Periodic observations of survival and development have been made, and the stand was thinned in 1951 and 1956.

Accomplishments: Some accomplishments are reported in:

Buckman, Robert E., and Roland G. Buchman. 1962. Red pine plantation with 48 sources of seed shows little variation in total height at 27 years of age. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 616, 2 pp., illus.

Cooperators: Northeastern Forest Experiment Station.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; James P. King, Associate Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-24. Camp-8 Red Pine Seed Source Study. 111.1. *Pinus resinosa.* (8-12)

Object: To explore the morphological and physiological variation in red pine assembled from much of its natural range.

Methods: Red pine seed was collected from native trees in more than 150 localities over the Lake States, the Northeast, and Canada. Stock was grown at the Cass Lake Nursery, Minn., and was field-planted in three localities in 1931 (37 sources) and 1933 (154 sources). Only the northeastern Minnesota plantation escaped drought and fire damage. On it, observations of growth and development have been made periodically and will be continued.

Accomplishments: Height, d.b.h., and survival were measured in 1964. There were differences between seed sources in height, d.b.h., and survival but these differences were small when compared to other pine species. Seed source growth and survival decreased with increasing distance of the source from the test plantation. This verifies earlier findings: Northeastern United States, Lower Michigan, and central Wisconsin sources generally are poorer than those from localities closer to the planting site in northeastern Minnesota. Some accomplishments are reported in:

Nienstaedt, Hans. 1964. Red pine progeny tests — 1931 and 1933 Minnesota plantings. Proc. Ninth Meeting Comm. on Forest Tree Breeding in Canada. Part II. Petawawa Forest Experiment Station, Chalk River, Ontario. Pp. 151-156.

Rudolf, Paul O. 1964. Some evidence of racial variation in red pine (*Pinus resinosa* Ait.) Proc. Ninth Meeting Comm. on Forest Tree Breeding in Canada. Part II. Petawawa Forest Experiment Station, Chalk River, Ontario. Pp. 143-149.

Assignment: James P. King, Associate Plant Geneticist; Hans Nienstaedt, Principal Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-25. Interregional Provenience Study of Eastern White Pine. 111.1. *Pinus strobus.* (8-13)

Object: (1) To clarify the magnitude and nature (clinal or discontinuous) of genetic diversity in eastern white pine, and (2) to determine which proveniences are best adapted to different sections of the Lake States.

Methods: Eastern white pine seed was collected from 17 localities over the botanical range of the species. Stock from 13 of these sources are being grown by various cooperators in Canada, the Lake States, the Northeast, the Central States, and the Southeast. Some plantings in each region follow a standard plan. Others follow alternative plans. Observations of survival and development have been or will be made in the nursery at 1, 2, and 5 years after field planting, and at intervals thereafter.

Accomplishments: Seed of 17 sources was sown in the U.S. Forest Service Nursery at Watersmeet, Mich., in the spring of 1958. Because of poor germination of some lots, supplemental sowings were

made in the spring of 1959 at the Hugo Sauer State Nursery at Rhinelander, Wis. Some source-related differences in growth appeared during the first year in the nursery. Field plots were established in 1962 and 1963 in Minnesota, Wisconsin, and Michigan.

Cooperators: Ontario Department of Lands and Forests; Northeastern Forest Experiment Station; Central States Forest Experiment Station; Southeastern Forest Experiment Station; Michigan Technological University; Quetico-Superior Wilderness Research Center; and Ottawa National Forest.

Assignment: Hans Nienstaedt, Principal Plant Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-26. Geographic Variation in Scotch Pine. 111.1. *Pinus sylvestris.*

Object: To study the survival, growth and development of Scotch pine from 109 geographic origins, planted on Sparta sand. Information will be obtained on (1) the range of geographic variation in the species, and (2) whether the soil and elevation as well as geographic location have caused genetic differentiation in the species. (See study 3-1.)

Methods: Stock of the 109 geographic sources was outplanted in 4-tree plots and replicated 10 times in a randomized complete block design. Each replication contained 436 trees spaced at 8 x 8 ft. The trees were examined at the end of the first year for height growth and other obvious characters that developed. They will be re-examined at 5-year intervals.

Accomplishments: Outplanting was established April 4, 1961. A survival count was taken July 23, 1961.

Cooperators: Department of Forestry, Michigan State University; Michigan Department of Conservation; University of Michigan.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-27. Northern Plains Scotch Pine Seed Source Study. 111.1. *Pinus sylvestris.*

Object: To test Scotch Pine of known origin for suitability to the Northern Great Plains, especially for shelterbelts and windbreak planting.

Methods: Seed of 24 Russian seed sources was received in the fall of 1956 and was raised in the Hugo Sauer Nursery at Rhinelander, Wis., and the Towner Nursery at Towner, N. Dak., to 2-2 stock. Seed from an additional nine sources was grown to 2-1 stock at the Petawawa Forest Experiment Station at Chalk River, Ontario, and was sent to the Towner Nursery in 1960. All 33 sources came from an area between 50° and 60° North latitude and between 37° and 124° East longitude.

One planting was installed on the Denbigh Experimental Forest, and two more in southeastern North Dakota. Measurements for height, d.b.h, and resistance factors have been or will be taken the first, second, fifth, and tenth years after planting.

An additional planting was established in 1963 with material acquired by Dr. Jonathan Wright of Michigan State University from 30 more sources from the Balkan States, Poland, Latvia, and western USSR.

Accomplishments: Present data indicate best height growth and survival rates in the progeny from trees growing in the western part of the USSR. Winter coloration (yellowing of foliage) was much less evident in 1964 than with the central European sources growing in the area. Variation is indicated in tendencies toward proleptic growth among the various seed sources.

Cooperators: North Dakota School of Forestry; Rocky Mountain Forest and Range Experiment Station, Lincoln, Neb.; and Forest Nursery Station, Indian Head, Saskatchewan.

Assignment: David H. Dawson, Plant Geneticist.

9-28. Hemlock Racial Variation Test, Argonne Experimental Forest. 111.1. *Tsuga canadensis.* (8-15)

Object: To explore variation, particularly in morphological and physiological characteristics, over the entire range of eastern hemlock.

Methods: Eastern hemlock seeds of known origin were assembled by the Connecticut Agricultural Experiment Station in 1953 and grown there as 1-2 stock. In the spring of 1957, stock of 16 origins was transplanted at the Hugo Sauer Nursery near Rhinelander, Wis.; it was field-planted in the spring of 1958 on the Argonne Experimental Forest.

Accomplishments: Nursery observations indicated some differences in frost damage in northeastern Wisconsin. Field plots were established in 1958. Study now closed.

Results were reported in the following:

Nienstaedt, Hans. 1958. Height growth is indicative of the relative frost resistance of hemlock seed source. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 525, 2 pp., illus.

Nienstaedt, Hans and J. S. Olson. 1961. Effect of photoperiod and source on seedling growth of eastern hemlock. Forest Sci. 7: 81-96.

Cooperators: The Connecticut Agricultural Experiment Station.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-29. A Study of Inheritance in White Spruce. 112, 14. *Picea glauca.*

Object: (1) To determine the magnitude and nature of genetic variation in white spruce, (2) to determine correlations between genetically controlled tree characteristics, (3) to determine correlations between juvenile and mature tree characteristics, (4) to evaluate the efficiency of various tree breeding methods.

Methods: The study will consist of a series of tests conducted over an unspecified length of time. Each test will bring together white spruce material of known genetic relationship into test plantings

designed to evaluate separately the effects of environment and genetic makeup on phenotypic expression. Half-sib, full-sib, and clonal material of parent trees will be included in the tests.

Accomplishments: Seed was sown in the Hugo Sauer Nursery, Rhinelander, Wis., in the spring of 1964 and 1965. Preliminary grafts were made in 1964-1965.

Cooperators: National Forests of the Lake States have provided outplanting sites.

Assignment: James P. King, Associate Plant Geneticist.

9-30. Self- and Cross-Fertility in Northern Tree Species as Influenced by Gamma Irradiation of Pollen. 112.0, 112.1. *Picea glauca, Pinus resinosa.*

Object: To determine the influence of various levels of gamma irradiation of pollen on cross- and self-compatibility and to compare the effectiveness of a given pollen radiation dosage on self-compatibility and on intraspecific cross-compatibility.

Methods: Three white spruce trees were pollinated in 1964 with their own pollen irradiated at 0, 300, 600, 900, and 1,200 *r* with five replications per pollen dosage. In 1965, three red pines were selfed and four were cross-pollinated with pollen from a common male parent; pollen irradiation dosages used were 0, 300, 600, 900, 1,200, 1,500 and 10,000 *r*. All tests were replicated. Seed yield will be determined, seed quality studied by means of X-radiography, and seedling development studied in the greenhouse and field.

Accomplishments: Seed from the white spruce pollinations has been extracted and is being analyzed. Seed from the red pine pollinations will be collected and analyzed in the autumn of 1966.

Assignment: Thomas D. Rudolph, Plant Geneticist.

9-31. Jack Pine-Lodgepole Pine Hybrids. 112.01. *Pinus banksiana, P. contorta.*

Object: To test crosses of jack pine with lodgepole pine along with the two parent species at several localities in the Lake States.

Methods: The seed was produced at the Institute of Forest Genetics at Placerville, Calif. The stock, grown at the Hugo Sauer Nursery in Wisconsin, was field-planted in the spring of 1953 in north-central Minnesota, northeastern Wisconsin, and central Lower Michigan in small replicate lots. Included were lodgepole pine of California origin, jack pine of Wisconsin origin, three crosses between the two (with *P. banksiana* the pollen parent), the backcross of the hybrid to jack pine, and the backcross of the hybrid to lodgepole pine.

Accomplishments: Five-year examinations indicate distinct differences in growth and survival between the various lots and between localities. In general, jack pine has made the best growth and lodgepole pine the poorest, with the backcross to jack pine second best, the F_1 hybrids next, and the backcross to lodgepole pine next to the poorest. In survival, the hybrids have done as well as or better than jack pine. Rust infection follows the same pattern as height growth, with lodgepole pine severely infected. The north-central Minnesota plot was examined in 1964. Height and d.b.h. were measured and pine-oak rust was scored as present or absent. Some results are given in:

Rudolph, T. D. and Hans Nienstaedt. 1962. Polygenic inheritance of winter injury in jack pine-lodgepole pine hybrids. Jour. Forestry 60: 138-139.

Cooperators: Pacific Southwest Forest Experiment Station.

Assignment: Hans Nienstaedt, Principal Geneticist; Paul O. Rudolf, Principal Silviculturist.

9-32. Eastern White Pine-Western White Pine Hybrids. 112.01. *Pinus monticola, P. strobus.* (8-17)

Object: To test crosses of eastern white pine with western white pine along with the two parent species at several localities in the Lake States.

Methods: The seed was produced at the Institute of Forest Genetics at Placerville, Calif. The stock, grown at the Hugo Sauer Nursery in Wisconsin, was field-planted in small lots in the spring of 1954 in north-central Minnesota, northeastern Wisconsin, and central Lower Michigan. Included were western white pine of California and Idaho origins, eastern white pine of Wisconsin and New Hampshire origins, and five crosses of the two species (with *P. strobus* the pollen parent in each instance). One lot of local eastern white pine was planted in each plantation.

Accomplishments: Five-year examinations indicate distinct differences in growth and survival, with eastern white pine generally best, the hybrids intermediate, and western white pine poorest. Results in the three localities differ, but the general pattern is similar. The hybrid with the Idaho western white pine parent has outgrown that with the California western white pine parent.

Cooperators: Pacific Southwest Forest Experiment Station.

Assignment: Hans Nienstaedt, Principal Geneticist; Paul O. Rudolf, Principal Silvicuturist.

9-33. The Effect of Gamma Irradiation of Pollen on Embryo, Seed, and Seedling Progeny Development in White Spruce. 112.11, 151.1. *Picea glauca.*

Object: To determine the effect of gamma irradiation of pollen at various dosages on embryo development, seed yield and quality, and on seedling development in white spruce; to test the hypothesis that irradiation of one parent prior to fertilization results in a heterotic effect due to heterozygosity for radiation-induced chromosome translocations.

Methods: Eight white spruce trees were pollinated in 1962 with pollen from a single tree irradiated at 0, 400, 600, and 800 roentgens. The study was repeated in 1964 on a larger scale using pollen dosages of 0, 300, 600, 900, and 1,200 *r*. All

tests were replicated. Seed yields from the 1962 pollinations have been determined, the seed germinated in the greenhouse, and replicated plots established in the nursery. Seeds from the 1964 pollinations will be X-radiographed to aid in quality evaluation and then sown in the greenhouse for study of germination behavior, mutation frequency, and seedling development. Microscopic preparations have been made of the developing embryos collected at weekly intervals during the 1962 season.

Accomplishments: Results from the 1962 pollinations showed significantly higher seed yields and germination percentages after pollination with pollen exposed to 600 *r* than with non-irradiated pollen. These and other results are discussed in:

Rudolph, T. D. 1964. The effect of gamma irradiation of pollen on seed characteristics in white spruce. Proc. FAO-IAEA Tech. Meeting on the Use of Mutations in Plant Breeding, Rome, Italy, May 25-June 1, 1964: 185-191, illus.

Cooperators: Biology Department, Brookhaven National Laboratory.

Assignment: Thomas D. Rudolph, Plant Geneticist.

9-34. The Effect of X-Irradiation of Seed on the Mutation Rate in the X_1 and X_2 Generation in Jack Pine. 112.11, 141. *Pinus banksiana.*

Object: To determine the effects of X-irradiation of seed on the mutation rate in the first- and second-generation progeny by comparison with open-pollinated and selfed, non-irradiated populations.

Methods: Seedlings grown from jack pine seed X-rayed with 2,000 roentgens in 1951 are now producing seed. Open-pollinated, selfed, and backcross progenies have been grown from 90 of these trees. The selfed pollinations have been studied on an individual pollination basis to aid in determining the possible existence of chimeras in the X_1 trees. Similar large progeny lots have been grown from non-irradiated populations to determine the natural mutation rates and for comparison with the rates in the irradiated population. Pollen sterility is also studied in the irradiated populations.

Accomplishments: More than 800 aberrant seedlings have been isolated from the various populations grown. Preliminary evidence indicates that a number of mutations may have resulted from the seed irradiation. A preliminary summary of the results is presented in:

Rudolph, T. D. 1965. The Effect of X-Irradiation of Seed on X_1 and X_2 Generation Progeny in Jack Pine. Proc. SAF Forest Genetics Workshop, Hickory Corners, Mich. October 1965. (In press.)

Assignment: Thomas D. Rudolph, Plant Geneticist.

9-35. The Effect of Gamma Radiation on Female Gametophyte and Embyro Development in Jack Pine. 112.11, 151.3. *Pinus banksiana.*

Object: (1) To determine the effects of various chronic and acute dosages of gamma radiation on female gametophyte and embryo development in jack pine; (2) within the effective dosages to determine if and at what stage of development embryo development breaks down, and (3) to determine the effect on gametophyte and embryo development of relatively high intensities of gamma radiation applied in one acute treatment at various times during the growing season.

Methods: Approximately 650 three-year-old flowering jack pine seedlings have been irradiated in the Gamma Field at Brookhaven National Laboratory and planted at Rhinelander. Chronic irradiation treatments have been applied to a portion of the seedlings at Brookhaven. Periodic cone and conelet collections have been made throughout the growing season and will be analyzed. Seed analysis will be carried out at Rhinelander.

Accomplishments: Material has been irradiated and replanted at Rhinelander. Cone and conelet collections are received and awaiting analysis.

Cooperators: Biology Department, Brookhaven National Laboratory.

Assignment: Thomas D. Rudolph, Plant Geneticist.

9-36. Seed Crop Report. 122, 222. General. (8-18)

Object: To obtain a systematic record of seed production of the more important forest tree or shelterbelt species in several localities in the Lake States and North Dakota.

Methods: Beginning in 1946, annual observations were made each autumn until 1962, of the seed crop (in proportion of a full crop) for the more important tree species in each research center territory of the Lake States Forest Experiment Station.

Accomplishments: The annual seed crop reports were published from 1949 to 1962 by the Lake States Forest Experiment Station as Technical Notes 333, 349, 370, 393, 412, 426, 447, 501, 540, 565, 574, 598, 615, and Research Note LS-8. The study was closed in 1963.

Assignment: Paul O. Rudolf, Principal Silviculturist.

9-37. Conelet Production on Branch Tips of Red Pine in Relation to Presence and Absence of Second-Year Cones. 122, 151.0. *Pinus resinosa.*

Object: To determine whether formation of conelets on branch tips (last 2 years of branch growth) is independent of the presence of cones on these tips and whether there exists any correlation between number of conelets formed and number of cones present.

Methods: Cone-bearing primary and secondary branch tips were sampled in several stands in August and numbers of cones and conelets recorded. Chi-square and regression analyses are being applied to these data.

Accomplishments: Data collected, analyses in progress.

Assignment: William E. Miller, Principal Insect Ecologist; John T. Eschle, Assistant Insect Ecologist.

9-38. Impact of Insects on Seed Crops in North-Central Seed-Production Areas. 122.0, 152.0. *Picea glauca, Pinus echinata, P. resinosa.*

Object: To record trends in insect attack in relation to seed production for the purpose of devising insect forecast schemes useful to the manager.

Methods: Samples of cones and conelets are collected annually according to detailed specifications in red pine, white spruce, and shortleaf pine seed-production areas. The numbers of cones, conelets, and degree of insect infestation are recorded in the laboratory.

Accomplishments: Several years' data have now been collected for red pine. Seed losses due to insects have been high, averaging roughly half the crop. The conelet-cone ratio seems to have value for forecasting the cone crop 1 year in advance.

Assignment: William E. Miller, Principal Insect Ecologist.

9-39. Springwood-Summerwood Transition Studies in Red Pine Seedlings. 151.0, 151.32. *Pinus resinosa.* (8-19)

Object: To determine (1) the relationship between the cessation of terminal elongation and the transition of springwood to summerwood, and (2) the effect of exogenous applications of auxin on growth ring formation in decapitated seedlings.

Methods: Potted red pine seedlings were held under long-day and short-day conditions and combinations of these two conditions with and without applications of auxin. Summerwood development was determined by dissection of the seedlings.

Accomplishments: Study closed. Results were reported in:

Larson, Philip R. 1960. A physiological consideration of the springwood-summerwood transition in red pine. Forest Sci. 6: 110-122.

Assignment: Philip R. Larson, Principal Plant Physiologist.

9-40. Fall Grafting of Spruce. 151.02. *Picea glauca.* (8-20)

Object: (1) To develop a reliable grafting method for white spruces of seedbearing age during the time of seed harvest in the fall, (2) to develop methods for grafting white spruce of different ages on white spruce rootstocks in different stages of development in the nursery as well as in the field.

Methods: (1) Scions of white spruce of two ages of wood from 30- to 60-year-old trees were collected in the fall and grafted by three methods on potted stock plants of Norway and white spruces. Stock plants were given different day-length treatments before grafting; and the grafted plants, long-day and natural-day treatments after grafting. (2) Scions from ortets of different ages were grafted on rootstocks of varying ages in the field. Graft position and covering were studied and the effects of fertilization on ortet and stock plants explored. Grafting was done from July 3-August 16, 1961, and in May, June, July, and August 1962.

Accomplishments: (1) Survival was 70 to 100 percent and showed effects of rootstock and postgrafting treatments in a few cases only. Photoperiod and temperature treatments after grafting, however, had considerable effect on scion activity and total growth. The best postgrafting treatment was 4 weeks of long-day followed by 2 weeks of short-day, then 8 weeks chilling, and finally long-day. (2) In the study of field grafting of white spruce it was found that covering grafts with kraft paper or polyethylene bags was detrimental to grafts made in the summer. Five-year-old rootstocks gave better results than 2-2 stock in the nursery or older rootstocks established in the field. Success with 5-year-old and 30-year-old scion material was greater than with scions from 60-year-old trees. Effects of fertilizing ortet and rootstock were inconclusive. Almost all grafts made in the summer of 1961 failed to survive. Spring and summer grafts made in 1962 survived much better, but differences between fertilizer treatments were not immediately apparent. Survival of spring 1962 grafts ranged from 30 to 90 percent. Survival of grafts made from July 17 through August 14, 1962, ranged from 0 to 90 percent using scions from both 60-year-old and 30-year-old trees. All grafts of the same age range attempted in late August and in September failed to survive. Results are included in the following publications:

Nienstaedt, Hans; Cech, Franklin B.; Mergen, Francois; Wang, Chi-Wu; and Zak, Bratislav. 1958. Vegetative propagation in forest genetics research and practice. Jour. Forestry 56: 826-839, illus.

Nienstaedt, Hans. 1959. The effect of rootstock activity on the success of fall grafting of spruce. Jour. Forestry 57: 828-832.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-41. Growth and Differentiation of Coniferous Tissue Maintained in Sterile Culture. 151.02. *Picea glauca.*

Object: To study the basic factors which affect growth and differentiation of white spruce apical meristems in sterile culture with particular reference to the influence of age of ortet, clone, and various chemical and physical factors of the culturing environment on these two physiological processes.

Methods: Terminal buds are collected from first- and second-order terminals, needles are removed from stems, and the cone of bud scales pulled off.

The meristem is removed from the twig and placed in culture tubes containing a sterile medium.

Accomplishments: Several bio-assay techniques have been developed.

Assignment: Bruce E. Haissig, Associate Plant Geneticist.

9-42. Chilling Requirements for Breaking Bud Dormancy in White Spruce. 151.04, 151.05. *Picea glauca.* (8-23)

Object: To determine (1) the minimum chilling requirements of white spruce seedlings, and (2) if long-day treatments compensate for these chilling requirements.

Methods: One-year or two-year seedlings of white spruce, dug after the terminal buds had stopped elongating in late July or early August, were potted. Part were placed in the greenhouse; and part were held in cold storage at natural daylength (13-hour), then removed to the greenhouse after 2 to 16 weeks' cooling at 36° F., and held at natural or long daylength (20-hour). Observations were made on bud swelling, exposure of needles, and beginning of terminal elongation. Another set of seedlings was potted in mid-September and exposed to the same treatments.

Accomplishments: Results so far indicate that to break dormancy of white spruce plants on 13-hour daylength requires 6 to 8 weeks of chilling if treatments begin in July and 4 to 6 weeks if begun in September. Long-day treatments compensated fully for lack of chilling in the July series but were not quite as effective in the September series. Manuscripts prepared but not yet published are:

Nienstaedt, Hans. Dormancy phenomena in white spruce, *Picea glauca* (Moench) Voss.

————————. Chilling requirements in seven *Picea* species.

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-43. A Study of the Growth of Four Northern Conifers in a Southern Nursery With Long-Day. 151.04, 154.2. *Picea glauca, P. mariana, Pinus resinosa, P. strobus.* (8-22)

Object: To study the growth and development of red and white pines and black and white spruces of Lake States origin in a north Florida nursery under natural and 20-hour day and to compare this stock with that grown from identical seed lots in northeastern Wisconsin under natural and 20-hour day.

Methods: Black spruce, white spruce, red pine, and eastern white pine seed were obtained from stand collections in the fall of 1956. Part of the seed was sown in the Olustee Experimental Forest Nursery, Florida, in December 1957. Artificial lighting commenced as soon as germination began, and it continued until 4 weeks before the average date of the first killing frost. The second season, lighting started soon after the start of extension growth and ceased on the same date as in the first year. A second part of the seed was sown in the Hugo Sauer State Nursery, Wisconsin, in the spring of 1958 in an identical experimental design. A high nutrient level was maintained at both nurseries. The growth and development of the stock were measured at frequent intervals. Stock from both the Florida and Wisconsin nurseries was field-planted on the Pike Bay Experimental Forest in northern Minnesota in the spring of 1962.

Accomplishments: Under long-day, stock of all four species grew about twice as fast in the southern nursery as in the Lake States nursery. The added daylight also somewhat increased the growth of spruces, but not of pines in the Lake States nursery. In the field, southern-grown 2-0 stock has done about as well as northern-grown stock (2-2) of similar size but greater age and cost. Some results are presented in:

Watt, Richard F. 1961. Artificially extended photoperiod increases size of nursery stock. Univ. Minn., Forestry Note 104, 2 pp.

Watt, Richard F. and William H. Davis McGregor. 1963. Growth of four northern conifers under long and natural photoperiods in Florida and Wisconsin. Forest Sci. 9: 115-128.

Cooperators: Southeastern Forest Experiment Station; Wisconsin Conservation Department; and University of Minnesota.

Assignment: R. F. Watt, Principal Plant Physiologist.

9-44. Auxin-Summerwood Relationships in Physiologically Mature Red Pine. 151.32, 151.0. *Pinus resinosa.* (8-25)

Object: To determine whether a correlative relationship exists between auxin metabolism and the initiation of summerwood formation in red pine.

Methods: Red pine branch samples were collected from the upper one-third of the crown in 15 vigorous, full-crowned trees 25 to 35 years old, at regular intervals between mid-May and mid-August. The branches were segmented into the bud or growing point, the current internode, and the previous year's internode. Within 3 hours after collection, auxin was ether-extracted from the bud and the current internode, and bioassays were made. Anatomical observations of summerwood development were made of typical specimens at each collection date. Observations on growth and development were made at each date.

Accomplishments: Data and observations have been accumulated for analysis. Some results are given in:

Larson, Philip R. 1962. Auxin gradients and the regulation of cambial activity. *In* Tree Growth; T. T. Kozlowski, ed.; pp. 89-96. Ronald Press, N.Y.

Assignment: Philip R. Larson, Principal Plant Physiologist.

9-45. Ponderosa Pine Susceptibility to European Pine Shoot Moth (*Rhyacionia buoliana*) **in Michigan.** 152.0, 111.1, 111.0. *Pinus ponderosa, P. resinosa.*

Object: To assess long-term susceptibility of ponderosa pine to attack and damage by the European pine shoot moth.

Methods: Six outplantings of several ponderosa pine seed sources were established in Lower Michigan in 1960. Red pine was included in the design for comparison purposes. Twice a year, insect populations are measured on each tree.

Accomplishments: The first 5 years' data reveal little if any difference in susceptibility to shoot moth attack between ponderosa and red pine. The growth of the two species has been roughly equal.

Cooperators: Pacific Northwest Region, U.S. Forest Service.

Assignment: Louis F. Wilson, Insect Ecologist; William E. Miller, Principal Insect Ecologist.

9-46. Control of Hibernating Red Pine Cone Beetles. 152.0. *Pinus resinosa.*

Object: To determine whether various treatments will reduce the beetle population during its hibernating period on the forest floor.

Methods: Half-acre plots in a red pine seed-production area received prescribed burning or ethylene dibromide (EDB) treatments replicated five times in the spring. Beetle survival following treatments was determined on many sub-plots within each plot.

Accomplishments: Prescribed burning killed 100 percent of hibernating beetles while EDB was totally unsatisfactory.

Assignment: William E. Miller, Principal Insect Ecologist.

9-47. Red Pine Cone Bagging to Determine Timing of Attack by Insects. 152.0, 151.08, 122, 154.03. *Pinus resinosa.*

Object: To determine (1) the time range of cone attack by insect species, (2) the period when greatest attack occurs by species, and (3) the relationship of attacks to phenology of the host and surrounding vegetation.

Methods: Fine-mesh, translucent plastic bags are placed on cone clusters early in the spring. Some bags are removed each week for 1 week, then replaced so that some cones are exposed for known periods to insect attack. At the end of the growth season, all cones are scored for kind of insect attack.

Accomplishments: Two years' data show that red pine cone beetle adults (*Conophthorus resinosae*) feed on cones the last half of May, then return in the last half of June to lay eggs. Eggs of the cone moth *Eucosma monitorana* are laid from the middle of June to the end of July.

Assignment: William E. Miller, Principal Insect Ecologist.

9-48. Controlled Pollination of White Spruce. 154.0, 112.0. *Picea glauca, P. mariana, P. omorika, P. rubens.* (8-27)

Object: To determine (1) the most effective bag types for pollination, (2) the developmental stage at which the female strobili show optimum receptivity, and (3) species- and self-compatibility.

Methods: (1) Tested were kraft, sausage casing, polyethylene, and cloth pollination bags alone and in combinations. (2) Bagged white spruce flowers were pollinated six times at 2-day intervals beginning at time of pollen shedding. (3) *Picea glauca, P. mariana, P. omorika,* and *P. rubens* were control-pollinated with pollen of each other and with pollen of *P. koyamai, P. orientalis, P. asperata, P. montigena, P. pungens, P. maximowiczi, P. retroflexa, P. jezoensis,* and *P. sitchensis.*

Accomplishments: (1) The combination of sausage casing and kraft bag has been accepted as most desirable. (2) White spruce female flowers are receptive over a period of 3 to 5 days (*See* Nienstaedt, Hans. 1958. Receptivity of female strobili of white spruce. Forest Sci. 4: 110-115, illus.) (3) None of the interspecific crosses gave good results; selfing studies have not yet been made. Arboretum material now assembled at Rhinelander represents more than 25 species of spruce. Six species are being provenance-tested. Controlled crosses made between 1956 and 1964 yielded seed that produced material now being tested for hybridity and suitability for later outplanting.

Cooperators: Morton Arboretum; Morris Arboretum; Highland Park Herbarium (Rochester, N.Y.).

Assignment: Hans Nienstaedt, Principal Plant Geneticist.

9-49. A Study of Compatibility in the Genus *Betula*. 211.0, 211.1, 211.3, 212.0. *Betula* spp.

Object: (1) To determine the amount of self-compatibility present in the native and the most important exotic birch species; (2) to determine whether intraspecific incompatibilities in birch exist, both between individuals of the same population and between trees of different geographic origins; (3) to determine which species of the genus *Betula* can be intercrossed and to what degree they are compatible; (4) to attempt to develop methods of overcoming compatibility barriers.

Methods: As many birch species as will survive the climate will be established in a breeding arboretum near the Institute of Forest Genetics. The study will include tests of self-compatibility, intraspecific compatibility, and interspecific compatibility within most of the native species. Some crosses will be made on bottle grafts in the greenhouse. Additional crosses will be made in the field, principally on the Argonne Experimental Forest, in the breeding arboretum, and in a number of planned seed source plantings. Seed result-

ing from the crosses will be harvested and tested for germinability. Seedlings developing from interspecific hybridization and selfing will be tested in replicated field plots with appropriate controls whenever possible. Attempts at overcoming incompatibilities will include: pollination of immature stigmas, pollination late in the period of female receptivity, amputation of styles, pollination at low temperature, irradiation of pollen mother cells, and possibly other methods.

Accomplishments: Results so far indicate that self-compatibility in birch usually is very low. Two trees have been found, however, which had 11 and 14 percent germination respectively of selfed seed. Intraspecific compatibilities have varied greatly with the individuals used in the crosses. The results of interspecific crosses, when successful, often differ, depending on which species is used as the female or the male parent.

Cooperators: University of Minnesota, Department of Horticulture; Arnold Arboretum; Morris Arboretum; Canada Department of Agriculture, Research Branch, Morden, Manitoba; Highland Park Arboretum (Rochester, N.Y.); Holden Arboretum (Mentor, Ohio); New York Botanical Garden; U.S. National Arboretum; Northeastern Forest Experiment Station; Morton Arboretum; Institut für Forstgenetik u. Forstpflanzenzüchtung, Schmalenbeck, West Germany.

Assignment: Knud E. Clausen, Associate Plant Geneticist.

9-50. A Study of Natural Variation in Yellow Birch. 211.1, 251.3, 251.0. *Betula alleghaniensis.*

Object: (1) To determine the patterns of variation in yellow birch over its entire range; (2) to determine the possible occurrence of distinct morphological and/or physiological races within the species; (3) to determine possible correlations between characteristics of juvenile and adult trees; (4) to provide a diversity of genotypes for use in studies of inheritance and in practical improvement work.

Methods: Seed has been obtained from about 55 geographic origins covering the entire range of the species. The seedlings have been transplanted at the Hugo Sauer Nursery in four randomized blocks. Field plantings will be established in four locations in the Lake States, using a randomized block design with 4-tree plots and 15 replications. Morphology, phenology, quality, and growth of the seedlings will be studied intensively in the nursery. Field survival will be checked periodically, and height and d.b.h. measured at 5-year intervals. Possible resistance to insects and/or disease will be noted. The plantings will be thinned twice.

Accomplishments: Catkins and seed have been collected from 10 to 15 trees in each of about 55 different locations. Catkin length and five bract characteristics have been measured in 55 collections, and significant differences between these sources have been demonstrated. The study has been seeded in the lath house and transplanted to the nursery.

Cooperators: Central States Forest Experiment Station; Northeastern Forest Experiment Station; Southeastern Forest Experiment Station; Southern Forest Experiment Station; Petawawa Forest Experiment Station; Canada Department of Forestry, Forest Research Branch at Sillery, Quebec, St. John's, Newfoundland, and Fredericton, New Brunswick; Michigan Technological University, Department of Forestry; State University College of Forestry at Syracuse University; Ontario Department of Lands and Forests at Sault Ste. Marie and Owen Sound, Ontario.

Assignment: Knud E. Clausen, Associate Plant Geneticist.

10. University of Michigan, School of Natural Resources

(Ann Arbor, Mich. 48104)

10-1. International Larch Provenance Test. 111.1, 111.0, 112.01. *Larix decidua, L. leptolepis.* (9-1)

Object: To test the survival, growth rate, and quality of various provenances of larch for possible planting in Michigan, to cooperate with researchers in 12 other countries to determine the plasticity of the respective provenances, and to study the variation pattern in European Larch.

Methods: Seed from 24 provenances was sown in the nursery in 1958. Seedlings from 12 sources were planted in the spring of 1960 in a randomized block design: 2 blocks, 12 sources, 72 trees per plot. A second outplanting was made in the spring of 1961, using 2-1 stock of 20 sources; a replicated, fully-randomized design was adopted. Height measurements were taken annually in the fall on every tree in the 1960 plantation. Heights of trees in the 1961 plantation were measured for the first time in the fall of 1964.

Accomplishments: Results to date show: Larch germination was poor. Field survival was generally high (70 to 100 percent); the source with poorest survival was from Ina, Japan. The Dunkeld hybrid (*Larix decidua* x *Larix leptolepis*); the Schlitz, Germany, source; and sources from the more continental parts of Europe have shown fastest height growth.

Cooperators: Professor R. Schober, Institut für Forsteinrichtung und Forstliche Ertragskunde, Forstliche Fakultät, Univ. Göttingen. Hann. Münden, Germany.

Assignment: Burton V. Barnes, Assistant Professor.

10-2. Insects Associated with Regional Jack Pine Seed Source Study. 152.0, 111.1. *Pinus banksiana.* (9-2)

Object: To study incidence of insect attack and degree of damage on jack pine sources at two outplantings in Michigan. (See study 9-17.)

Methods: Insect damage was evaluated and measurements taken on the seed source plots near Pellston and Watersmeet, Mich.

Accomplishments: The severe insect damage on the Pellston plot was not directly associated with seed source. Data from this plot must be analyzed with full cognizance of insect attack.

Cooperators: Lake States Forest Experiment Station.

Assignment: Fred B. Knight, Professor; James Sutherland, graduate student.

10-3. Natural Variation in *Populus.* 211.0, 211.1, 211.3, 243, 251.32, 212.01. *Populus grandidentata, P. tremuloides.* (9-3)

Object: To study the extent and pattern of natural variation in the two native aspens, and the genetic and environmental factors responsible for the observed variation.

Methods: Field and laboratory studies to investigate differences in gross morphology, flushing, flowering, growth rate, stem quality, and pest resistance between and within aspen clones.

Accomplishments: (1) Hybridization between the aspens is relatively common in southeastern Michigan, but relatively rare in the northern part of the Lower Peninsula. Results are published in:

Barnes, Burton V. 1961. Hybrid aspens in the Lower Peninsula of Michigan. Rhodora 63: 311-324.

(2) Naturally occurring bigtooth aspen clones were selected for good vigor, stem form, and pest resistance on good, medium, and poor sites on the University of Michigan Biological Station Forest. The selected clones were superior in height, diameter, and volume to adjacent random clones. Results are presented in:

Koenig, Robert L. 1960. Variation in tree size and quality of naturally occurring bigtooth aspen clones in northern Lower Michigan. Master's thesis, 68 pp.

(3) Wood-quality investigations were also conducted on the selected and randomly paired clones studied by Koenig. No significant differences were found in mean specific gravity between selected and randomly paired clones on the three sites. Results are presented in:

Albert, Thomas J. 1960. Specific gravity variation of naturally occurring bigtooth aspen clones in northern Lower Michigan. Master's thesis, 60 pp.

(4) The combined effects of large interclonal variation and the structure of aspen stands, that develop in clones of genotypically identical stems, can be of equal or greater importance in site quality variation than soil and topography. Since all dominant ramets of an aspen clone have a similar height-age pattern, measurement of one clone, regardless of the number of dominants measured, is equivalent to the measurement of one tree. Where six clones or more of *P. grandidentata* are present on a given site, a selection of three representative clones for measurement will yield a satisfactory estimate of site quality. Results are published in:

Zahner, Robert, and Ned A. Crawford. 1965. The clonal concept in aspen site relations. *In* C. T. Youngberg (Ed.) Forest-Soil Relationships in North America, pp. 229-243. Oregon State Univ. Press., Corvallis.

(5) Relationships between juvenile and mature foliage are being investigated by Howard R. Alden, Assistant Professor, University of Idaho, Moscow.

Cooperators: Lower Michigan Pulpwood Research Association.

Assignment: Burton V. Barnes, Assistant Professor; James Bertenshaw, graduate student.

10-4. The Spread of Naturally Occurring Bigtooth Aspen Phenotypes of Desirable Vigor and Form. 23, 211.3. *Populus grandidentata.*

Object: To develop techniques to promote the spread of bigtooth aspen phenotypes in stands where they compete with less desirable clones and undesirable species.

Methods: Root suckering and spread of naturally occurring bigtooth aspen clones were investigated by testing partial cutting, clear cutting, and cutting sequences on individual clones. A large-scale test of cutting sequences was established following the initial cutting trials.

Accomplishments: A large phenotypic variation in suckering ability between clones was found, independent of cutting treatment. Significantly fewer living suckers were found in the partially cut areas than in clear-cut areas. The clonal variation in suckering obscured the effect of various clearcutting treatments. Results are published in:

Garrett, Peter W. and Robert Zahner. 1964. Clonal variation in suckering of aspen obscures effect of various clearcutting treatments. Jour. Forestry 62: 740-750.

Cooperators: Lower Michigan Pulpwood Research Association.

Assignments: Robert Zahner, Professor.

10-5. Sexual and Asexual Propagation of *Populus* **species.** 221, 212.01, 251.02, 251.01, 211.3. *Populus grandidentata, P. tremuloides.*

Object: (1) To develop relatively easy and inexpensive methods of producing aspen by sexual and asexual means under greenhouse and nursery conditions for research and production, (2) to study the physiology of flowering, seed production, and root suckering of the aspens, and (3) to select and propagate superior phenotypes under controlled conditions and in selected natural environments.

Methods: Controlled pollinations are made, seeds are collected and sown, and seedlings transplanted in the arboretum or field sites. Physiological investigations are conducted in the nursery, greenhouse, and growth chamber. Superior phenotypes are selected, propagated, and outplanted.

Accomplishments: (1) Relationship of root suckering to apical dominance was demonstrated. Results are published in:

Farmer, Robert E. 1962. Aspen root sucker formation and apical dominance. Forest Sci. 8: 403-410.

(2) The effect of light intensity on height growth of greenwood cuttings of trembling aspen under two temperature regimes was investigated and reported in:

Farmer, Robert E. 1963. Effect of light intensity on growth of *Populus tremuloides* cuttings under two temperature regimes. Ecology 44: 409-411.

(3) Vegetative propagation of aspen species was described in:

Farmer, Robert E. 1963. Vegetative propagation of aspen by greenwood cuttings. Jour. Forestry 61: 385-386.

(4) Sixteen superior phenotypes of bigtooth aspen were selected in the northern half of the Lower Peninsula of Michigan. Superior phenotypes had a significantly higher cubic-foot and rough cord volume per tree than paired random clones. Results are presented in:

Romeril, Allan B. 1961. Selection of genetically superior clones of bigtooth aspen. Master's thesis, 57 pp.

(5) Ramets of the superior clones were propagated from root cuttings by Howard Alden. Striking differences in suckering ability between the clones were found.

Cooperators: Lower Michigan Pulpwood Research Association.

Assignment: Burton V. Barnes, Assistant Professor.

11. University of Minnesota: School of Forestry; Department of Plant Pathology and Physiology; Horticultural Science Department; and North Central Experiment Station at Grand Rapids, Minn.

(St. Paul Campus, St. Paul, Minn. 55101)

11-1. The Natural Distribution of Jack Pine in Minnesota. 111, 151.4. *Pinus banksiana.* (10-7)

Methods: Field observation and studies of herbarium records.

Accomplishments: A distribution map was prepared (see Schoenike, 1962) which differed in three major respects from previously published range maps. These include: (1) a break in the species range in northern Beltrami and part of Koochiching Counties, (2) near absence of jack pine from a large area in east-central Minnesota centering about Mille Lacs Lake and Kanabec County, and (3) absence of the species along Lake Superior from Duluth to Hovland and for distances from 5 to 20 miles inland. Results were published in:

Schoenike, R. E. 1961. A revised range map for jack pine in Minnesota. Minn. Forestry Notes No. 109. (Univ. of Minn. Agric. Expt. Sta. Science Jour. Ser. No. 4723).

Schoenike, R. E. 1962. The distribution of jack pine in Minnesota. Minn. School of Forestry Special Pub. No. 1. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Series Paper No. 4762.) 57 pp.

Rudolf, Paul O and R. E. Schoenike. 1963. Botanical and commercial range of jack pine in the Lake States. U.S. Forest Serv. Res. Note LS-15, 4 pp. Lake States Forest Expt. Sta., St. Paul, Minn.

Cooperators: Herbaria of the University of Minnesota (Minneapolis and Duluth); Quetico-Superior Wilderness Research Center; Lake States Forest Experiment Station; Minnesota Department of Conservation.

Assignment: Scott S. Pauley, Professor, and Research Assistants.

11-2. Seed Source and Open-Pollinated 1-Tree Progeny Tests of Pine Species. 111.0, 111.1, *Pinus banksiana, P. resinosa, P. sylvestris.*

Object: To test seed sources of native and exotic pine species for adaptability in Minnesota and for use in a selective pine breeding program. (See study 3-2.)

Methods: Replicated outplantings.

Accomplishments: About 150 sources of Scotch pine and 50 sources of red pine have been established in 15 outplantings between 1961 and 1964. Ninety-six sources of jack pine are currently in the nursery and will be outplanted in 1966. All of the pine seed source studies were initiated in cooperation with Michigan State University as part of the Regional Cooperative Project NC-51 ("Improvement of forest trees through selection and breeding"). Some results appear in:

Pauley, Scott S., M. A. K. Khalil, and W. H. Cromell. 1965. NC-51 Scots pine seed source tests in Minnesota. Univ. Minn. Forestry Notes No. 162.

Wright, J. W., S. S. Pauley, R. B. Polk, J. J. Jokela, and R. Read. 1965. Genetic responses of Scotch pine in the North Central Region. Silvae Genetica (In press.)

Cooperators: Michigan State University; North Central Experiment Station; Blandin Paper Co.; Minnesota Conservation Department; Cloquet Forest Research Center; Diamond National Corp.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-3. Screening Tests of Exotic Pine Species and Putative Hybrids. 111.0, 112.0. *Pinus contorta, P. ponderosa, P. rigida,* and *P. virginiana.*

Object: To test various pine species and putative hybrids for adaptability in Minnesota and for use in a selective pine breeding program.

Methods: Replicated outplantings.

Accomplishments: Seed lots of pitch pine, Virginia pine, ponderosa pine, and lodgepole pine from promising sources and several putative hybrids of these species have been established in 10 outplantings.

Cooperators: Blandin Paper Co.; North Central Experiment Station; Cloquet Forest Research Center; Branch Tree Farm; Institute of Forest Genetics, Placerville, Calif.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-4. Seed Source Tests of White Fir. 111.1. *Abies concolor.*

Object: To identify the best adapted sources for planting in Minnesota and for use in a fir selective breeding program. (See also study 3-1.)

Methods: Replicated outplanting.

Accomplishments: Under the NC-51 program, 16 sources of white fir 1-0 stock were obtained from Michigan State University in 1963. The material was lined-out in the North Central Experiment Station nursery. The stock, now 2-1, is highly variable in adaptability to the nursery environment in which it has been grown at Grand Rapids. One replicated outplanting of promising sources was made in spring 1965.

Cooperators: Michigan State University; North Central Experiment Station; Blandin Paper Co.; Cloquet Forest Research Center.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11.5 Seed Source Tests of Tamarack. 111.1. *Larix laricina.*

Object: To isolate the best adapted sources for Minnesota and for use in a selective larch breeding program.

Methods: Replicated nursery propagation and outplantings.

Accomplishments: Tamarack seed from 62 sources was assembled and sown in the North Central Experiment Station nursery in 1962 and 1963. Seed from 64 sources (some new and some repeats) was acquired in autumn 1964 and planted in spring 1965. The project is a part of the NC-51 program. Seed lot samples of all sources have been supplied to cooperators in Wisconsin (Lake States Forest Experiment Station, Rhinelander) and Michigan (Michigan State University).

Some accomplishments are reported in:

Pauley, S. S. 1965. Seed sources of tamarack, *Larix laricina* (Du Roi) K. Koch. Proc. Central States Forest Tree Imp. Com., Lincoln, Neb., Oct. 2, 1964.

Schoenike, Roland E. 1961. The genus *Larix* — a literature review. 61 pp. (Mimeo.)

Cooperators: Lake States Forest Experiment Station; North Central Experiment Station; Michigan State University; State, Federal, Provincial, and Dominion Forest services.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-6. Seed Source Tests of Japanese Larch. 111.1. *Larix leptolepis.*

Object: To identify the most suitable seed sources for planting in Minnesota and for use in a selective breeding program. (See also study 3-1.)

Methods: Replicated outplanting.

Accomplishments: Two outplantings of six sources were established in 1960 and 1961. These seed source studies were initiated in cooperation with Michigan State University as part of the Regional Cooperative Project NC-51. Some results appear in:

Pauley, Scott S., C. A. Mohn, and W. H. Cromell. 1965. NC-51 Japanese larch seed source tests in Minnesota. Minn. Forestry Notes No. 157. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5621.)

Cooperators: Michigan State University; North Central Experiment Station; Blandin Paper Co.

Assignment: Scott S. Pauley, Professor, and Research Assistants.

11-7. Seed Source and Putative Hybrid Tests of Spruce Species. 111.1, 111.0, 112.01. *Picea abies, P. glauca, P. rubens.* (10-2, 10-9)

Object: To test seed sources of native and exotic spruce species and putative hybrids for adaptability in Minnesota and for use in a selective spruce breeding program. (See studies 9-13, and 9-16.)

Methods: Replicated outplantings are established in various localities throughout the State and periodically measured.

Accomplishments: Several putative species hybrids and 47 white spruce, 5 Norway spruce, and 14 red spruce seed sources have been established in plantations at Gunn Park, Burgeson's Landing, Cloquet, North Central Experiment Station (Grand Rapids), and St. Paul, Minn.

Cooperators: Blandin Paper Co.; North Central Experiment Station; Cloquet Forest Research Center; Branch Tree Farm; Petawawa Forest Experiment Station; U.S. Forest Service, Lake States Forest Experiment Station.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-8. Variations in Bark Thickness of Jack Pine Seed Sources. 111.1. *Pinus banksiana.*

Object: To determine if bark thickness—d.b.h. ratios vary significantly among the 25 jack pine seed sources established at the Cloquet Forest Research Center in 1942-43.

Methods: Data are collected and statistically analyzed for the 1942-43 jack pine seed source plantations at the Cloquet Research Center.

Accomplishments: Thick-bark trees are essentially limited to sources from the south and west portions of the Lake States; thin-bark trees are mostly found in sources originating in the Far North and on the East Coast; bark thickness of sources from Minnesota declines rapidly and quite uniformly from the southwest to the northeast; bark thickness of sources from Michigan declines rapidly from south to north. The data suggest that selective breeding for thin-bark or thick-bark trees is feasible.

Schoenike, R. E., and B. A. Brown. 1963. Variation in bark thickness of jack pine seed sources. Minn. Forestry Notes No. 130. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5103.)

Cooperators: Cloquet Forest Research Center.

Assignment: R. E. Schoenike (Associate Professor, Clemson University, Clemson, S.C.); B. A. Brown, Assistant Professor, Cloquet Forest Research Center.

11-9. Variation in Branch Characteristics of Jack Pine Seed Sources. 111.1. *Pinus banksiana.*

Object: To determine if branching characteristics vary significantly among 23 of the jack pine seed sources established at the Cloquet Forest Research Center in 1942-43.

Methods: Data are collected and statistically analyzed for the 1942-43 jack pine seed source plantations at the Cloquet Research Center.

Accomplishments: The results, partly reported in the following publication, indicate that selective breeding for branch and crown characteristics in jack pine is feasible:

Schoenike, R. E., T. D. Rudolph, and R. A. Jensen. 1962. Branch characteristics in a jack pine seed source plantation. Minn. Forestry Notes No. 113. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 4775.)

Cooperators: Cloquet Forest Research Center.

Assignment: R. E. Schoenike (Associate Professor, Clemson University, Clemson, S.C.); R. A. Jensen, Assistant Scientist, Cloquet Forest Research Center.

11-10. Studies of Variation in Slash Pine Gum Yield. 111.1, 111.2, 111.3. *Pinus elliottii.*

Object: To determine (1) the effects of the grafting rootstock on the gum-yielding ability of the scion; (2) variation in gum-yielding ability of slash pines selected for form and vigor; (3) the effects of vigor and geographic origin upon gum yield of trees grown in a uniform environment; and (4) the heritability of gum yield in the population studied.

Methods: Seedlings of known origin and vigor were planted in a uniform environment; scions from trees of known gum yield were grafted on several stocks; selections for high gum-yielding ability were used as parents in controlled crosses. All material was tested for gum yields.

Accomplishments: Trees in this experiment two or more standard deviations above the mean yielded approximately two to three times more gum than the average tree. Breeding for increased gum yield should produce progeny with a potentially outstanding gum-yielding ability in comparison to the population from which the parents were selected. This probability of rapid return on selection for gum yield may be very profitable, especially when individuals are first chosen on the basis of vigor and form. Some results are reported in:

Peters, W. J. 1965. A study of the variation in slash pine (*Pinus elliottii* Engelm.) gum yielding potential. M.S. Thesis, Univ. of Minn. 51 pp.

Cooperators: School of Forestry, University of Florida.

Assignment: William J. Peters (Present address: University of Florida, Gainesville, Fla.)

11-11. Growth Patterns of *Pinus sylvestris* L. Provenances in Minnesota. 111.1, 151.08, 144. *Pinus sylvestris.*

Object: To determine variation in seasonal growth patterns of Scotch pine sources in Minnesota as related to described varieties and evolutionary trends within the species. (See study 3-1.)

Methods: Periodic measurements in five NC-51 Scotch pine outplantings in Minnesota.

Accomplishments: Weekly measurements in two outplantings were made in the 1965 season. Similar measurements will be made in these and three additional plantings in 1966.

Cooperators: Michigan State University; Blandin Paper Co.; Minnesota Department of Conservation; Cloquet Forest Research Center.

Assignment: M. A. K. Khalil, Graduate Student.

11-12. Seed Source Tests of Douglas-Fir. 111.1. *Pseudotsuga menziesii.*

Object: To identify the best adapted sources for planting in Minnesota and for use in a Douglas-fir selective breeding program. (See also study 3-1.)

Methods: Replicated outplanting.

Accomplishments: In cooperation with Michigan State University under the NC-51 program, 64 Douglas-fir seed sources were obtained as 1-0 stock in 1963 and lined-out in the North Central Experi-

ment Station nursery. On the basis of nursery performance the sources are highly variable in frost resistance and height growth. One outplanting of promising sources was made in spring 1965.

Cooperators: Michigan State University; North Central Experiment Station; Blandin Paper Co.; Cloquet Forest Research Center.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-13. Seed Source Tests of Northern White-Cedar. 111.1. *Thuja occidentalis.*

Object: To identify the best adapted sources for planting in Minnesota and for use in a northern white-cedar selective breeding program.

Methods: Replicated nursery propagation and outplantings.

Accomplishments: Thirty-two range-wide seed sources of northern white-cedar were assembled through the assistance of a large number of cooperators in the United States and Canada in autumn 1964. Sample seed lots were supplied NC-51 cooperators in Wisconsin, Michigan, and Illinois. A replicated nursery sowing was made at the Cloquet Research Center in spring 1965.

Cooperators: North Central Experiment Station; Lake States Forest Experiment Station; Michigan State University; University of Illinois.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-14. Selection for Tracheid Length in Loblolly Pine. 111.2, 111.3, 141, 142. *Pinus taeda.* (10-13)

Object: To determine the feasibility of selective breeding for tracheid length and to compute heritability and genetic gain estimates for the populations studied.

Methods: The parents and the progeny of controlled crosses are analyzed.

Accomplishments: Data for this study have been collected and analyzed; writing of the thesis is in progress.

Cooperators: School of Forestry, University of Georgia.

Assignment: James T. Greene, Graduate Student.

11-15. Studies on the Resistance of Jack Pine to the Endemic Rusts of Minnesota. 111.3, 151.5. *Pinus banksiana.* (10-12)

Object: To gain information on the biology of the various rust species which infect jack pine in the Lake States. To test the inheritance of resistance of putatively resistant trees.

Methods: Rust-free trees are selected in stands which have a high incidence of the disease. Scions from these trees are grafted onto jack pine understocks. When the grafts are 2 to 3 years old they are inoculated artificially. A continuing search is maintained for new rusts on jack pine.

Accomplishments: Two previously unknown species of rust have been found to be present on Minnesota jack pine. These species are *Peridermium harknessii* and *P. stalactiforme*. Pine grafted in 1958 now average 10 feet in height. No male strobili have formed on these trees, but female cones have formed on each tree. Some results are given in:

Anderson, Neil. 1960. Stalactiform rust on jack pine in Minnesota. Forest Sci. 6: 40-41.

——————— and D. W. French. 1964. Sweetfern rust on jack pine. Jour. Forestry 62: 467-471.

——————— and D. W. French. 1965. Western gall rust in the Lake States. Forest Sci. 11: 139-141.

Cooperators: Lake States Forest Experiment Station, Cloquet Forest Research Center.

Assignment: Neil A. Anderson, Associate Professor, and David W. French, Professor, Plant Pathology Department, University of Minnesota.

11-16. Field Tests of the Open-Pollinated Progeny of Rosendahl Spruce (White x Black Spruce) and Its Parental Species. 112.01. *Picea glauca, P. mariana.*

Object: To determine the probable pollen source of the open-pollinated progeny and adaptability of the segregates for outplanting.

Methods: Replicated and unreplicated outplantings of the OP hybrid and parental species are outplanted and studied.

Accomplishments: Outplantings have been established at Gunn Park and Cloquet. Morphological characteristics of the twigs indicate that most plants probably are derived from backcrosses of the hybrid to black spruce. The segregates of this hybrid may be adapted to a wider range of habitats than either of the parental species. Testing on a variety of sites in Itasca County is planned for the plants currently being propagated. Some results are reported in:

Little, Elbert L. and Scott S. Pauley. 1958. A natural hybrid between black and white spruce in Minnesota. Amer. Midland Nat. 60 (1): 202-211.

Cooperators: Blandin Paper Co.; North Central Experiment Station; Minnesota Department of Conservation; Cloquet Forest Research Center.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-17. White Spruce Seedling Seed Orchard Study. 122.1. *Picea glauca.*

Object: To establish a white spruce seedling seed orchard through recurrent selection.

Methods: Open-pollinated progeny of randomly selected native trees are propagated and established in a well replicated outplanting. Based on

performance, a small percentage of the family lines will be retained and their progeny, in turn, will be tested.

Accomplishments: Propagation of 282 mother-tree lines was started in a replicated nursery planting in 1963.

Cooperators: Blandin Paper Co.; North Central Experiment Station; Minnesota Department of Conservation; Quetico-Superior Wilderness Research Center.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-18. Studies of the Inheritance of "Closed" and "Open" Cones in Jack Pine. 141. *Pinus banksiana.* (10-6)

Object: To determine the mode of inheritance.

Methods: Replicated outplantings are made of progenies from controlled crosses.

Accomplishments: Two six-replicate outplantings of 25 lots of seed from controlled crosses involving "open-" and "closed-"cone trees were established in 1963-64.

Cooperators: Cloquet Forest Research Center; North Central Experiment Station; Blandin Paper Co.; Minnesota Department of Conservation.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-19. Studies of the Inheritance of Fastigiate and "Weeping" Branch Traits in Jack Pine. 141. *Pinus banksiana.*

Object: To determine mode of inheritance.

Methods: Outplantings of open-pollinated seed from fastigiate and "weeping" trees.

Accomplishments: One open-pollinated progeny of a fastigiate and one open-pollinated progeny from a "weeping" tree were outplanted in 1964.

Cooperators: Horticulture Department, University of Minnesota; North Central Experiment Station; Blandin Paper Co.

Assignment: Albert G. Johnson, Associate Scientist, Horticulture Department; and Scott S. Pauley, Professor, School of Forestry.

11-20. Studies of Witches' Brooms in Jack Pine and Their Segregating Progenies. 141, 112.1. *Pinus banksiana.*

Object: To determine the cause of brooming in jack pine, the mode of inheritance of "dwarf" and "normal" segregates from broom-seed, and growth and development of the segregates.

Methods: Replicated nursery and field plantings are made of open-pollinated broom-derived seed.

Accomplishments: A 2-year nursery study was made in 1962-63. The material was established in a permanent outplanting in 1964. On the basis of the nursery tests, broom-derived seed segregated normal-dwarf in a 1:1 ratio. Chi-square tests indicated that the probability that this ratio was not due to chance was greater than 0.70. Such a 1:1 segregation ratio suggests that the brooms are derived from a dominant somatic mutation or "bud sport." Some results are given in:

Johnson, A. G., S. S. Pauley, and W. H. Cromell. 1965. Dwarf seedlings from witches' brooms in jack pine. I. Minn. Forestry Notes No. 158.

———————. 1965. Dwarf seedlings from witches' brooms in jack pine. II. Minn. Forestry Notes No. 163.

Cooperators: Horticulture Department, Univ. of Minn.; North Central Experiment Station; Cloquet Forest Research Center.

Assignment: Albert G. Johnson, Associate Scientist, Horticulture Department; Scott S. Pauley, Professor, School of Forestry; William H. Cromell, Instructor, North Central Experiment Station.

11-21. Studies of the Inheritance of Seed and Seed Wing Characters in Slash Pine. 141. *Pinus elliottii.*

Object: To (1) measure the parent-progeny relationships of seed, and seed wing characters of a selected population of slash pine; and (2) determine, if possible, the mode of inheritance of one or more of the traits studied.

Methods: Seed of known parents and their progenies have been collected and their characteristics will be compared and analyzed.

Accomplishments: Collections have been made and data are being analyzed.

Cooperators: Southeastern Forest Experiment Station.

Assignment: John F. Kraus, Graduate Student.

11-22. Constancy and Repeatability of Morphogenetic Activity in Uni-Nodal Pines. 142. 151.08, 151.3. *Pinus* spp.

Object: To determine the range of reaction — within and between genotypes — of shoot apices to environmental influences and meristematic aging.

Methods: Tree crowns will be examined morphologically and the phenology of morphogenesis will be studied in shoot apices.

Accomplishments: The project is in the planning stage.

Assignment: Ronald M. Lanner, Graduate Student.

11-23. Microsporogenesis and Early Pollen Forcing in Rosendahl (White x Black) Spruce and its Parental Species. 151.01, 151.08, 151.1. *Picea glauca, P. mariana.*

Object: To compare the cytology and phenology of normal and forced microsporogenesis of white, black, and Rosendahl spruces and to determine the feasibility of obtaining viable pollen by early forcing in order to facilitate hybridization between these taxa.

Methods: Staminate strobiles are forced on cuttings exposed in the greenhouse.

Accomplishments: Viable pollen was successfully forced from winter-collected cuttings of white, black, and Rosendahl spruces. The natural time difference in flowering was overcome, thus providing a tool for interbreeding these taxa. During forcing and natural development on the trees, pollen always shed from white spruce first, then from the hybrid, and finally from black spruce. Using departures from long-range weather averages, a heat-requirement difference was postulated for each species to account for the time difference in their flowering. Some results are reported in:

Winton, Lawson L. 1964. Microsporogenesis and early pollen forcing in a white x black spruce hybrid and its parental species. 146 pp. (Ph.D. Thesis, Univ. of Minn.)

———————. 1964. Phenology of normal and forced microsporogenesis in white and black spruce and their F hybrid. Minn. Forestry Notes No. 153. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5513.)

———————. 1964. Meiosis and pollen release in white and black spruce and their hybrid. Minn. Forestry Notes No. 154. (Univ. of Minn. Agric. Expt. Sta. Sci. Jour. Ser. No. 5512.)

———————. 1964. Cessation of dormancy in white spruce. Minn. Forestry Notes No. 155. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5514.)

———————. 1965. Early pollen forcing in a white x black spruce hybrid and its parental species. Jour. Minn. Acad. Sci. 32 (2): 103-105.

Cooperators: Blandin Paper Co.; North Central Experiment Station; Minnesota Department of Conservation.

Assignment: Lawson L. Winton (Present address: Inst. of Paper Chemistry, Appleton, Wis.)

11-24. The Reproductive Cycle of Blue Spruce. 151.08, 151.01, 151.3. *Picea pungens.*

Object: To investigate the phenological and morphological characteristics of microsporogenesis and megasporogenesis and gametogenesis in blue spruce.

Methods: Both field and laboratory studies are made.

Accomplishments: The different species of spruce have apparently been geographically isolated with little or no natural opportunity for gene flow. A geographic isolating mechanism, rather than an internal one, has likely been the main source of speciation in this genus. Some results are given in:

Fechner, Gilbert H. 1964. The reproductive cycle of *Picea pungens* Engelmann. 199 pp. (Ph.D. Thesis).

Cooperators: Colorado State University.

Assignment: Gilbert H. Fechner (Present address: Colorado State University, Fort Collins)

11-25. Natural Polyploidy in Juvenile White and Black Spruces. 151.1, 14. *Picea glauca, P. mariana.*

Object: To determine the kinds of natural polyploidy that may occur in juvenile white and black spruce populations and estimate their frequencies.

Methods: Morphological and cytological studies are made.

Accomplishments: Verification of 12 (haploid) and 24 (diploid) chromosome numbers for white and black spruce was made on a large number of juvenile plants in the Blandin Nursery in 1960, 1961, and 1962. Putative polyploids were identified for cytological examination on the basis of short, thick needles and long internodes.

Polyploid frequencies of 0.0096, 0.0070, and 0.0098 percent were found for 2-1 white spruce. Polyploid frequencies of 0.0049 and 0.0044 percent, respectively, were found for 2-1 and 1-2 black spruce. Some results are reported in:

Winton, Lawson L. 1963. Natural polyploidy in juvenile white spruce (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Miller) B.S.P.) 83 pp. (M.S. Thesis, Univ. of Minn.)

———————. 1964. Natural polyploidy in juvenile white and black spruce. Minn. Forestry Note No. 144. (Univ. of Minn. Agri. Expt. Sta. Sci. Jour. Ser. No. 5452.)

———————. 1964. External needle morphology of diploid and polyploid juvenile white and black spruce. Minn. Forestry Notes No. 145. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5451.)

———————. 1964. Cytotechniques for spruce chromosomes. Minn. Forestry Notes No. 146. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5450.)

Cooperators: Blandin Paper Co.; North Central Experiment Station; U.S. Forest Service.

Assignment: Lawson L. Winton (Present address: Institute of Paper Chemistry, Appleton, Wis.)

11-26. Seed Source Tests of Paper Birch. 211.1. *Betula papyrifera.*

Object: To test seed sources of paper birch for adaptability in Minnesota and for use in a selective breeding program.

Methods: Replicated outplantings are made.

Accomplishments: Six widely separated sources were established in two outplantings. The high-latitude sources are typically dwarfed and have little promise for Minnesota other than for ornamental purposes.

Cooperators: Diamond National Corp.; Plant Pathology Department, University of Minnesota.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-27. Aspen Seed Source Tests. 211.1, 211.0. *Populus adenopoda, P. alba, P. canescens, P. grandidentata, P. tremula, P. tremuloides, P. sieboldii.*

Object: To identfy seed sources of quaking aspen (*P. tremuloides*), bigtooth aspen (*P. grandidentata*), European aspen (P. *tremula*), Chinese aspen (*P. adenopoda*), and Japanese aspen (*P. sieboldii*) best adapted to Minnesota and for use in a selective breeding program.

Methods: Field trials are made of known material.

Accomplishments: A single unreplicated outplanting of several sources of quaking, bigtooth, European, and Japanese aspen; white poplar (*P. alba*); and gray poplar (*P. canescens* = *P. tremula* x *P. alba*) was established in the Forest-Tree Improvement Arboretum at Gunn Memorial Park, Grand Rapids (Prairie Lake) in 1956.

Outplantings of 46 seed sources of these species were also established by the Maria Moors Cabot Foundation for Botanical Research at Harvard University in eastern and central Massachusetts between 1947 and 1955. Through cooperation of the Cabot Foundation, these materials have been made available to the School of Forestry's Tree Improvement Project.

Similarity in growth and survival of the Lake States sources with those of Massachusetts and other northeastern U.S. sources when grown in Massachusetts suggests that the Massachusetts results are in general applicable to Minnesota. The Massachusetts results, based on 11- to 13-year-old trials, indicated that the high mortality and slow growth of western and high-latitude, short-growing-season sources of quaking aspen make them unsuited for planting in the northeastern U.S.

Similar results were obtained with high-latitude sources of European aspen. Some results are presented in:

Pauley, S. S. 1963. Performance of some aspen seed sources and hybrids in eastern Massachusetts. Proc. World Consultation on Forest Genetics & Tree Improvement. 17 pp. (Univ. Minn. Agr. Expt. Sta., Sci. Jour. Ser. Paper No. 5135.)

Pauley, S. S., A. G. Johnson, and F. S. Santamour. 1963. Results of aspen screening tests: I. Seed sources of quaking aspen (*P. tremuloides* Michaux). Minn. Forestry Notes No. 136. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. Paper No. 5171)

———. 1963. Results of aspen screening tests: II. Seed sources of European aspen (*Populus tremula* Linneaus). Minn. Forestry Notes No. 137. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. No. 5172.)

———. 1963. Results of aspen screening tests: III. F_1 hybrid progenies of quaking x European aspen. Minn. Forestry Notes No. 138. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. Paper No. 5173.)

Pauley, S. S., A. G. Johnson, and F. S. Santamour. 1963. Results of aspen screening tests: IV. F_1 hybrid progenies involving European, quaking, bigtooth and Chinese aspens. Minn. Forestry Notes No. 139. (Univ. of Minn. Agr. Expt. Sta. Sci. Jour. Ser. Paper No. 5174.)

Cooperators: Cabot Foundation, Harvard University; North Central Experiment Station; Blandin Paper Co.

Assignment: Scott S. Pauley, Professor; Carl A. Mohn, Instructor; and Research Assistants.

11-28. Cottonwood and Balsam Poplar Seed Source Tests. 211.1, 211.0. *Populus* Section *Aegeiros* and Section *Tacamahaca.*

Object: To test seed sources of native and exotic cottonwoods, balsam poplars, and hybrids of species in these sections of the genus for adaptability in Minnesota and for use in a selective breeding program.

Methods: Test plantations are made.

Accomplishments: An unreplicated outplanting of various sources of most native and exotic *Aegeiros* and *Tacamahaca* species was established in the Forest-Tree Improvement Arboretum at Gunn Memorial Park, Grand Rapids (Prairie Lake) in 1956.

Outplanting trials of more than 300 seed sources of balsam poplar and cottonwood species were established by the Maria Moors Cabot Foundation for Botanical Research at Harvard University in eastern Massachusetts between 1947 and 1955. Through cooperation of the Cabot Foundation, surviving sources of these collections have been made available to the School of Forestry's Tree Improvement Project.

In cooperation with the University of Illinois as part of the NC-51 program, 1-0 stock of 60 eastern cottonwood (*P. deltoides*) sources were outplanted at Rosemount in May 1965.

Cooperators: Rosemount Research Center; Cabot Foundation, Harvard University; University of Illinois.

Assignment: Carl A. Mohn, Instructor; and Research Assistants.

11-29. Seed Source Tests of Northern Red Oak. 211.1. *Quercus rubra.*

Object: To test seed sources of northern red oak for adaptability in Minnesota and for use in a selective breeding program.

Methods: Replicated outplanting.

Accomplishments: The stock for this study was supplied from Ohio as part of the NC-51 cooperative program. Two 14-source outplantings were established in 1964.

Cooperators: Ohio Agricultural Experiment Station; St. John's Abbey.

Assignment: Scott S. Pauley, Professor; and Research Assistants.

11-30. Clone Identification and Delineation in Aspen. 211.2. 251.0, 251.3. *Populus tremuloides.*

Object: To develop practical techniques for the identification and mapping of aspen clones in the field.

Methods: Study of colored aerial photographs.

Accomplishments: A method of rapid clone identification through the use of colored aerial photographs was developed. Since marked differences in leaf flushing of clones had been reported by many authors, the investigation made use of low-level colored aerial photographs to identify and delineate the boundaries of putative clones. Confirmation of clonal identity was based on sex, partition chromatography of vegetative bud extracts, and external morphological features, especially stem form and leaf shape.

The areas mapped in the Remer and Marcell, Minn., areas had clone sizes ranging from 0.4 to 35 acres. Results are reported in:

Blake, G. M. 1964. Clone identification and delineation in the aspens. 106 pp. (Ph.D. Thesis).

Cooperators: Chippewa National Forest; Lake States Forest Experiment Station.

Assignment: George M. Blake (Assistant Professor, Montana State University, Missoula); and Research Assistants.

11-31. Progeny Testing of Paper Birch. 212.0, 24. *Betula papyrifera.*

Object: To estimate the relative magnitude of dominance variance and additive genetic variance of one or more traits in paper birch.

Methods: Progenies of several seed parents and known pollen parents are being studied.

Accomplishments: Information on breeding value of individual trees, provided by progeny tests, is the appropriate basis of selection for traits in which additive genetic variance is responsible for a small proportion of total phenotypic variance. One of several alternative procedures for progeny testing is the use of a series of tester parents. Each tree being tested is crossed with all of the tester parents, and the average performance of the test-cross progenies for a tested parent is used as an estimate of its breeding value. As the number of tester parents is increased, the cost per tree being tested is increased, but the error in estimating breeding value, due to the presence of dominance effects, is reduced. A realistic estimate of the magnitude of dominance variance, relative to the magnitude of additive genetic variance, would be helpful in estimating the number of testers which would provide the best balance of economy and precision in a selection system.

The material for the experiment, consisting of test-cross progenies from 15 seed parents and 6 pollen (tester) parents, is currently being grown in the Gibbs-Nelson greenhouses at St. Paul.

Cooperators: Blandin Paper Co.

Assignment: Jerome Klein, Graduate Student.

11-32. Hybridization of the Aspens. 212.01, 212.02. *Populus,* Section *Leuce.*

Object: To (1) produce and test promising intra- and interspecific F_1 hybrids in the Section *Leuce* for outplanting in Minnesota; and (2) produce F_2 and backcross populations for segregation analyses within selected F_1 hybrid populations. (The F_1 populations, about 60 in number and involving chiefly species of the Section *Leuce,* were produced and outplanted in Massachusetts between 1948 and 1954.)

Methods: Controlled crosses and replicated outplantings.

Accomplishments: The Massachusetts results indicated that F_1 hybrid progenies of Massachusetts *tremuloides* x *tremula* of various latitudinal sources followed a similar relative pattern of performance to that of the seed sources. The most promising combinations involved *tremula* pollen sources of mid-latitude or Italian origin.

Combinations involving *P. grandidentata* and European and quaking aspen appear to be one of the most promising areas for further hybridization in the aspens.

More than 100 controlled crosses were made in the greenhouse (March and April 1965). Sufficient seed of about 40 cross combinations was obtained.

Cooperators: Cabot Foundation, Harvard University; North Central Experiment Station; Blandin Paper Co.

Assignment: Carl A. Mohn, Instructor.

11-33. Sex Ratio and Hermaphroditism in Aspen. 24. *Populus tremuloides.* (10-23)

Object: To study the sex ratio and frequency of bisexual trees in wild and cultivated populations of quaking aspen.

Methods: Wild populations and progeny of controlled crosses are under study.

Accomplishments: Sex ratios of 1:1 and departures from this ratio of 3:1 in favor of males have been reported for wild quaking aspen populations. If, as has been postulated, sex determination in the aspens is by the XY mechanism the ratio of males to females should approximate a 1:1 ratio. This is supported by recent determination of a 1:1 ratio in a half-sib population cultivated in the Gibbs-Nelson area. Departures from a 1:1 ratio in old populations may result from differential selection of the sexes or sampling errors.

Bisexuality in quaking aspen usually results from the presence of a few male flowers or an occasional bisexual flower on predominantly female trees. Such plants may represent genotypes in which the sex-determining mechanism may be altered by environmental influences.

Selfed and out-crossed hermaphrodites show well-marked bisexuality in their offspring, suggesting that genetic control of bisexuality may be strong in some lines.

Cooperators: North Central Experiment Station.

Assignment: Scott S. Pauley, Professor; and M. A. K. Khalil, Graduate Student.

11-34. Analysis of the P_1, F_1, and F_2 Generations of a North x South, Western Black Cottonwood Cross. 24, 251.08. *Populus trichocarpa.*

Object: To study F_2 segregation for the photoperiodic response, as measured in terms of time of height growth cessation; also leaf morphology, bud resin color, branching characteristics, bark anatomy, and other traits.

Methods: Controlled greenhouse crosses and replicated outplantings are made.

Accomplishments: One F_2 progeny derived from crossing F_1's of an Alaska x a Montana source of *P. trichocarpa* was produced in 1958 and, together with the original parents and individuals of the F_1, was outplanted in May 1965.

Additional F_2 progenies were obtained from crosses made in spring 1965 and will be ready for outplanting in 1966.

Cooperators: North Central Experiment Station; Cabot Foundation, Harvard University.

Assignment: Carl A. Mohn, Instructor.

12. University of Wisconsin, Departments of Forestry and Plant Pathology

(Madison, Wis. 53706)

12-1. Geographic Variation in Forest Tree Species. 111.1, 211.1. *Abies balsamea, Larix laricina, L. leptolepis, Pinus banksiana, P. ponderosa, P. resinosa, P. sylvestris, Populus deltoides.* (11-2)

Object: (1) To provide information on the range and pattern of genetic variation associated with geography as a basis for planning forest tree improvement programs (see also studies 3-1, 9-21, and 11-5), and (2) to assemble representative materials from diverse natural populations for breeding studies.

Methods: Measurements and scores of variation in several characters are being made on material collected from natural stands (balsam fir, tamarack) or on replicated common-environment studies in nurseries (balsam fir, tamarack) and in field plantings (red, Scotch, jack pines; Japanese larch). Within the next few years field plantings are to be made of jack pine, ponderosa pine, eastern cottonwood, and balsam fir.

Accomplishments: (1) Red pine — significant differences in total height, diameter, and frequency of lammas growth have been found in provenance tests ranging in plantation age from 8 to 11 years. (2) Japanese larch — significant differences in total height, frost susceptibility, flowering, and branching have been found in a test of seven sources at a plantation age of 5 years. (3) Balsam fir — significant differences in total height at a nursery age of 2 years have been found in a range-wide provenance test.

Results are discussed more thoroughly in:

Lester, D. T. 1964. Summary of comments on red pine breeding. Proc. Com. Forest Tree Breeding in Canada. pp. 157-161.

Lester, D. T. 1965. NC-51 provenance studies by the Wisconsin Agricultural Experiment Station. Fourth Central States Forest Tree Impr. Conf. Proc., pp. 35-37. (Published by Nebr. Agr. Expt. Sta.)

Lester, D. T. and G. R. Barr. 1965. Provenance and progeny tests in red pine. Forest Sci. 11: 327-340.

Rehfeldt, G. E. 1965. Shoot elongation and lammas growth in a red pine provenance trial. 118 pp. (M.S. thesis, Univ. Wisconsin.)

Cooperators: Wisconsin Conservation Department; members of the NC-51 Regional Project (Michigan State University, University of Illinois, University of Minnesota, Lake States Forest Experiment Station); Nekoosa-Edwards Paper Co.; and many seed collectors.

Assignment: D. Lester, Assistant Professor; T. A. Peterson and G. E. Rehfeldt, Graduate Students.

12.2. Interspecific Hybridization with Red Pine. 112.01. *Pinus nigra, P. resinosa.*

Object: To overcome the interspecific incompatibility barrier of red pine so that variation can be introduced through interspecific hybridization.

Methods: Interspecific crosses between several individuals of red and black pines have been attempted using the following techniques: (1) Reconnaissance crossing using several pollen mixes each representing five different trees, (2) pollen mixes containing from 1- to 30-percent pollen from the same species as the maternal parent, (3) low-dose irradiation of pollen to stimulate pollen tube development, and (4) high-dose irradiation of pollen to obtain physiological benefits of pollen from the same species as the maternal parent but without intraspecific fertilization.

Accomplishments: The cones produced by methods (1) and (2) are to be harvested in 1965.

Cooperators: Wisconsin Conservation Department; Lake States Forest Experiment Station.

Assignment: D. Lester, Assistant Professor.

12-3. Seedling Seed Orchards of Red Pine. 122.1, 111. *Pinus resinosa.*

Object: (1) To identify areas, stands, and individuals with genetic potential for improvement in growth, and (2) to establish a population with genetic potential for improved growth in each area of nursery stock distribution for Wisconsin State forest nurseries.

Methods: (1) Collection of open-pollinated seed from 10 trees per stand in stands representing each of the areas of nursery stock distribution, (2) sowing of the collections in small nursery plots in a highly replicated randomized block design, (3) lifting of each block separately at age 3-0 and replicated field planting with one plantation in each nursery area, (4) plantation evaluation at 6, 12, and 18 years after planting, (5) conversion to a seedling seed orchard at age 18 by thinning, in each block, to the best individual in each of the best 75 progenies in each plantation, and (6) eventual thinning in each block to the best individual of the best 15 progenies.

Evaluation of the orchards will be guided by results from currently established one-parent progeny tests. Before the age for conversion is finally set, juvenile-mature correlations in existing plantations will be available up to age 35.

Accomplishments: Seed collection is to be initiated in 1965.

Cooperators: Wisconsin Conservation Department.

Assignment: D. Lester, Assistant Professor.

12-4. Phase Change in Needle Ontogeny of *Pinus.* 151.0, 151.3. *Pinus* spp.

Object: (1) To determine the feasibility of using secondary needle initiation as a measure of physiological aging of apical meristems in pine seedlings, (2) environmentally to accelerate secondary needle initiation, and (3) to relate secondary needle initiation to reproductive maturation.

Methods: Controlled environment studies, nutritional studies, and heteroplastic micrografting will be used.

Accomplishments: Screening of 12 pine species in three photoperiods to identify two or three species for more intensive experimentation has been completed.

Assignment: D. Lester, Assistant Professor; R. T. Riding, Graduate Student.

12-5. The Nature and Expression of Resistance to White Pine Blister Rust. 151.5, 111.3, 112.02. *Pinus strobus.* (11-13)

Object: To determine (1) the external (environmental) and internal (genetic) factors which affect infection and subsequent establishment in the pine host of the blister rust fungus, *Cronartium ribicola,* and (2) the nature and expression of host resistance in individual tree selections. Such information is desirable to provide a firm base to a long-term cooperative regional program for the development and production of blister-rust-resistant white pines.

Methods: The nature of the infection process and of host reactions to infection will be studied by fluorescent microscopy and histochemical and cytochemical tests. Responses of susceptible and resistant selections to infection, and the course of disease development and resistance reactions will be studied on plants exposed to various controlled environmental conditions.

Accomplishments: Information on resistance of selections in the field and of variability in combining ability of individual tree selections has been obtained from previous work. Resistant material from tests of individual tree selections and progenies of controlled pollinations is now available for incorporation into the regional program for development of blister-rust-resistant white pine.

A technique for fluorescent labeling of basidiospores has been developed which should aid greatly in studies of host-parasite relations. A back-patch grafting technique has facilitated the use of standardized stem infections in environmental studies. Conditions of temperature and moisture stress influence the course of disease development, and presumably also, the expression of resistance reactions. Increase in resistance to infection with increasing age of stock has been shown. Also, there are indications that considerable variability in virulence exists among basidiospores of the blister rust fungus.

Cooperators: North Central Region, U.S. Forest Service; Lake States Forest Experiment Station; Wisconsin Conservation Department; Nekoosa-Edwards Paper Company; Quetico-Superior Wilderness Research Center.

Assignment: R. F. Patton, Professor.

12-6. Poplar Diseases and Disease Resistance. 211.0, 212.0, 251.5, 221. *Populus* spp. (11-14)

Object: To select, develop, and evaluate improved poplars suitable for Wisconsin growing conditions and resistant to major diseases; also, to investigate important diseases and their pathogens.

Methods: Scores of poplar selections and hybrids have been tested during the past 25 years in nursery and field plantings. Clones that have appeared "superior" for one or more characters have been increased, further tested in field plantings, and inoculated with disease pathogens in both field and greenhouse. Factors affecting initial establishment were evaluated with dormant and rooted cuttings of several sizes that had been planted at increasing depths.

Accomplishments: 30 clones have been selected for further testing on different sites in several Wisconsin areas. Native cottonwoods generally have done best. Rooted cuttings or long unrooted cuttings have provided greatest initial survival and subsequent growth. First-year weed, and espe-

cially grass, control is essential and has been achieved either mechanically or chemically. Responses (disease incidence and development) of selected clones to inoculations by *Hypoxylon pruinatum* (stem canker) and *Colletotrichum gloeosporioides* (shoot blight), as well as natural infections by a *Fusarium* canker and an unknown stem dieback, were studied.

Cooperators: Wisconsin Conservation Department; U.S. Forest Service North-Central Region; Nekoosa-Edwards Paper Co.; and several individuals.

Assignment: J. G. Berbee, Associate Professor.

12-7. Selections and Breeding for Resistance to Dutch Elm Disease. 211.3, 211.0, 212.0, 251.5. *Celtis* spp., *Hemiptelea* spp., *Holoptelea* spp., *Trema* spp., *Ulmus* spp., and *Zelkova* spp.

Object: To develop elm trees resistant to Dutch elm disease.

Methods: During the past 8 years over 400 seed collections or clones of members of the *Ulmaceae* have been introduced from many parts of the world. Plants from these introductions are being intensively screened for resistance to Dutch elm disease. Promising individuals are being grown in an arboretum for use in controlled breeding trials.

Accomplishments: Plants from these introductions now include some 37,000 seedlings growing in a 12-acre nursery at Arlington, Wis. Included in the collection are most of the elm species, as well as representatives from *Zelkova, Hemiptelea,* and *Celtis*. Tropical representatives held in the greenhouse include species of *Ulmus, Trema, Holoptelea,* and *Celtis*. Some of the early selections for resistance have now reached flowering age.

Cooperators: Members of the International Union of Forest Research Organizations, and other foreign, Federal, State, and private persons and agencies.

Assignment: E. B. Smalley, Associate Professor.

12-8. Wide Crosses in *Populus*. 212.01, 251.1. *Populus deltoides, P. tremuloides,* other *Populus* spp.

Object: To produce and identify monoploid seedlings through crosses between putative intersection hybrids.

Methods: Standard techniques of poplar breeding, seedling culture, and cytological screening by stomatal size measurements and chromosome counts.

Accomplishments: Progeny from several F_2 and backcrosses of putative *P. tremuloides* x *P. deltoides* hybrids are being raised. Chromosome counts have indicated several monoploids.

Assignment: D. Lester, Assistant Professor; J. G. Berbee, Associate Professor.

12-9. Oak Wilt: Its Development, Spread, and Control. 211.3, 251.5, 251.02. *Quercus ellipsoidalis, Q. macrocarpa, Q. rubra, Q. velutina,* other *Quercus* spp. (11-5)

Object: Within the important oak species, to find trees resistant to the oak wilt fungus; to devise effective methods for their propagation; to determine basic differences in disease development between the red and the white oak groups.

Methods: In the course of oak wilt investigations, scores of trees which have escaped natural infection have been inoculated artificially. In addition, red oak seedlings grown from acorns collected widely in eastern U.S. are being screened by inoculations.

Accomplishments: So far, all red, black, or northern pin oaks have succumbed either to single or to repeated inoculations. A number of the infected bur oaks have shown foliage symptoms the year of infection, but not thereafter. Both morphological and physiological differences between these two groups are being studied. Fungus mats develop and sporulate on bur and white oaks as well as on red oaks; the fungus persists for many years in the roots of infected bur oaks; and reinvasions of above-ground parts occur. Elsewhere, attempts to propagate oaks vegetatively have given variable results.

Cooperators: Wisconsin Conservation Department; Nekoosa-Edwards Paper Co.

Assignment: J. E. Kuntz, Professor; and V. M. G. Nair, Post-Doctorate Fellow.

DEVELOPMENTAL PROJECTS

13. Kimberly-Clark Corporation, Woodlands Division

(Neenah, Wis. 54956)

13-1. Seed Orchard Development. 122.1. *Picea glauca, P. mariana, Pinus resinosa.*

Object: To develop seed orchards composed of superior trees for white spruce, black spruce, and red pine.

Methods: Beginning in 1960, scions have been collected each year from superior white spruce, black spruce, and red pine trees. These scions were grafted to 2-2 transplant stock in the Lake Mary Nursery using the side-graft technique. In May 1965, the first outplantings were made in the seed orchard area near Cunard, Mich.

Accomplishments: Grafting success has been about 75 percent. Approximately 400 trees have been outplanted in the seed orchard area. An approximate breakdown by species is: white spruce 200, black spruce 150, and red pine 50.

Assignment: Jack B. Cody, Forest Entomologist.

14. The Mando Division of the Boise Cascade Corporation

(Big Falls, Minn. 56627)

14-1 Tree Improvement Program for Conifers. 122.1. *Abies balsamea, Picea glauca, P. mariana, Pinus banksiana, P. resinosa,* and *P. strobus.*

Object: To establish a seed orchard of about 1,000 stems for each important conifer, using selected stock from a wide geographical range of Mando holdings in Minnesota.

Methods: Seed is taken from selected trees within selected stands programmed for cutting each year in each District. About 20 of the best specimens from each source are outplanted into the seed orchard as 2-2 stock.

Accomplishments: The first stock was set out in the seed orchard in the spring of 1965. Complete records are being maintained on each tree.

Assignment: A. F. Ennis, Forester.

14-2. Propagation of Triploid Aspens. 251.02, 251.322. *Populus tremuloides.*

Object: To develop a continuing supply of rooted triploid aspen stems for outplanting.

Method: Root sections obtained from known triploids in the company's operating area are potted, and then the suckers are removed and placed in rooting media under fluorescent lights in a small indoor greenhouse.

Accomplishments: The program was initiated in the spring of 1965 and sprouts were in the rooting stage of development in August 1965.

Cooperators: The Institute of Paper Chemistry.

Assignment: A. F. Ennis, Forester.

15. Nekoosa-Edwards Paper Company, Woodlands Department

(Port Edwards, Wis. 54469)

15-1. Red Pine Seed Production Areas. 122.0. *Pinus resinosa.*

Object: To produce seed of known origin from selected trees for use in reforestation.

Methods: Natural stands of second growth and old growth are selected, improvement cuts are made to remove undesirable trees, and management for seed production follows.

Accomplishments: Two areas, one each near Ashland and Minocqua, Wis., have been selected, rogued, and put under management for seed production. Additional improvement cuts are scheduled in the Ashland area.

Assignment: E. E. Oilschlager, Forester.

16. U. S. Forest Service, North Central Region

(Milwaukee, Wis. 53203)

16-1. Selection of Superior Trees. 111.3, 122.1. *Picea glauca, P. mariana, Pinus banksiana, P. resinosa, P. strobus.*

Object: To locate, select, and identify individual trees of superior phenotypes for use in seed orchards.

Methods: Standards for height, volume, age, and quality have been established Regionwide. Superior tree candidates are reported by National Forest Ranger Districts, screened and checked by the Forest Supervisor's staff, and approved by the Regional Geneticist.

Accomplishments: Over 400 trees have been reported and screened since 1961; 34 trees have been accepted. The program is continuing.

Cooperators: Lake States Forest Experiment Station.

Assignment: J. Pitcher, Regional Geneticist, and staff members of the National Forests of the Lake States.

16-2. A Study of the Variation in Crown Efficiency of Red Pine Growing on the National Forests in the Lake States. 111.3. *Pinus resinosa.*

Object: To determine the extent of variation in the apparent efficiency of the tree crowns of red pine as an index to selection for improvement.

Methods: Measurements of total height, d.b.h., crown width, and length of live crown were made on 1,806 red pine trees. These were located on 6 National Forests in 3 States, covering 37 separate stands. The ratio of crown volume to stem volume was computed to determine relative efficiency of the crowns in producing stem wood. This ratio was expressed as "R" value.

Accomplishments: Preliminary analyses of the data indicate a linear relationship for R in which larger crown volumes produce greater stem volumes. R values were derived in the range 12 to 422 with the average R approximating 113. The study is continuing.

Cooperators: Lake States Forest Experiment Station.

Assignment: J. Pitcher, Regional Geneticist, and staff members of the National Forests in the Lake States.

16-3. Development of Seed Production Areas. 122.0. *Picea glauca, Pinus resinosa, P. strobus.*

Object: To develop and maintain seed production areas of sufficient capacity to satisfy the reforestation demands of the National Forests in the Lake States.

Methods: Selected high-quality natural and planted stands were rogued of undesirable trees. Selected seed trees were spaced about one-half tree height apart. Trees were pruned to the base of the live crown.

Accomplishments: 29 seed production areas covering 1,220 acres, including isolation zones, have been established for three species as follows: (1) *Pinus resinosa* — 18 seed production areas covering 846 acres. No seed collected to date. Average annual seed production anticipated is 1,200 lbs. (2) *P. strobus* — 2 areas totaling 78 acres on Michigan's Lower Peninsula. Anticipated yield is 200 lbs. per year. Seed from these areas will be used outside the high-hazard blister rust zones. (3) *Picea glauca* — 9 seed production areas totaling 297 acres. Annual yield of seed is expected to be 225 lbs. In 1964, collections from portions of three areas yielded over 66 lbs. of cleaned seed.

Cooperators: Lake States Forest Experiment Station.

Assignment: J. Pitcher, Regional Geneticist, and staff members of the National Forests in the Lake States.

16-4. The Development of Eastern White Pine: Resistance to Blister Rust. 122.1, 111.3, 112.0, 151.5, 151.02. *Pinus strobus.*

Object: (1) To extend the program initiated by the University of Wisconsin and reported in Lake States Forest Experiment Station, Station Paper No. 74, 1959. (See study 12-5.) (2) To establish and operate one or more eastern white pine seed orchards for the production of rust-resistant stock in cooperation with several conservation and research agencies.

Methods: (1) Existing parent material, tested for resistance transmission, will be used to establish interim seed orchards. (2) Approximately 650 rust-free eastern white pines will be selected from within areas of intense infection. These will be grafted into a clonal breeding arboretum for future use. Controlled pollination will be done on these selected trees in the field, using pollen from known resistant clones. The progeny from these crosses will be grown in the nursery, then submitted to heavy inoculation by rust spores. Ortets showing good general combining ability will be control-pollinated in the clonal breeding arboretum to assess specific combining ability. The best ortets will be multiplied and used to establish seed orchards for the production of improved seed. Progeny tests for growth and form will be run concurrently with the development of the seed orchard. Clones producing progeny of poor growth and form will be rogued.

Accomplishments: A cooperative agreement has been entered into by the participating agencies. Twenty-one rust-free candidates were located and screened in 1964. The search for additional candidates is continuing. A site has been selected for the clonal breeding arboretum and ground preparation is nearly complete. Rootstocks have been prepared for 3,000 grafts to be made during the winter of 1965-66. A total of 73 ramets from clones 18, 30, 312, 327, and 343, tested for resistance transmission, were made available by the University of Wisconsin. These were transplanted in 1965 at the Blister Rust Center, Watersmeet, Mich., for use as sources of pollen and scion material.

Cooperators: Lake States Forest Experiment Station; University of Wisconsin; Conservation and Agriculture Departments of the States of Michigan, Minnesota, and Wisconsin.

Assignment: J. Pitcher, Regional Geneticist, and staff members of the National Forests in the Lake States.

A TABULAR SUMMARY

Table 1.--Projects by agencies and genera

Genus	Research agency[1/]													Developmental agency[1/]					All agencies
	1	2	3	4	5	6	7	8	9	10	11	12	Total	13	14	15	16	Total	
Abies	..	..	1	..	..	..	1	..	1	..	1	1	5	..	1	..	..	1	6
Acer	..	..	..	2	..	..	..	..	..	..	..	..	2	..	..	..	..	0	2
Betula	..	..	..	..	..	..	..	..	3	..	2	..	5	..	..	..	..	0	5
Celtis	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	0	1
Fraxinus	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	0	1
Hemiptelea	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	0	1
Holoptelea	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	0	1
Juniperus	..	..	..	..	..	..	..	..	2	..	..	..	2	..	..	..	..	0	2
Larix	..	1	2	1	..	..	1	..	4	1	2	1	13	..	..	..	..	0	13
Picea	1	..	1	2	1	2	1	..	20	..	6	..	34	1	1	..	2	4	38
Pinus	..	1	6	5	1	3	2	1	26	1	14	5	65	1	1	1	4	7	72
Populus	..	5	1	..	..	..	..	2	..	3	6	3	20	..	1	..	..	1	21
Pseudotsuga	..	..	1	..	..	..	..	..	..	..	1	..	2	..	..	..	..	0	2
Quercus	..	..	2	..	..	..	..	..	..	..	1	1	4	..	..	..	..	0	4
Thuja	..	..	..	..	..	..	..	..	1	..	1	..	2	..	..	..	..	0	2
Trema	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	0	1
Tsuga	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	0	1
Ulmus	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	0	1
Zelkova	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	0	1
General	..	..	1	..	..	..	..	1	2	..	..	..	4	..	..	..	..	0	4
Total	1	7	15	10	2	5	5	5	60	5	34	17	166	2	4	1	6	13	179

1/ Numbers refer to agencies, 1 to 12 for research and 13 to 16 for developmental work, as follows:

1. Consolidated Papers, Inc.
2. The Institute of Paper Chemistry
3. Michigan State University
4. Michigan Technological University
5. Minnesota Department of Conservation
6. Nekoosa-Edwards Paper Co.
7. Quetico-Superior Wilderness Research Center
8. U.S. Forest Products Laboratory
9. U.S. Lake States Forest Experiment Station
10. University of Michigan
11. University of Minnesota
12. University of Wisconsin
13. Kimberly-Clark Corporation
14. The Mando Division, Boise Cascade Corporation
15. Nekoosa-Edwards Paper Company
16. U.S. Forest Service, North Central Region

Table 2A.--Projects by categories and genera (softwoods)[1/]

	Category	Abies	Juniperus	Larix	Picea	Pinus	Pseudotsuga	Thuja	Tsuga	General	Total
11	Natural variation	1	..	4	2	5	..	..	..	..	12
111.0	Natural variation among species	1	..	9	14	21	..	..	..	1	46
111.1	Natural variation among races	3	2	17	22	54	2	2	1	..	103
111.2	Natural variation among stands	..	..	..	..	2	..	..	..	..	2
111.3	Natural variation among individuals	..	..	..	3	14	..	..	..	..	17
112	Induced variation	..	..	..	1	..	..	..	..	..	1
112.0	Induced variation by recombination	..	..	..	6	6	..	..	..	..	12
112.01	Interspecific hybridization	..	..	8	2	10	..	..	..	..	20
112.02	Intraspecific hybridization	1	..	1	3	10	..	..	..	..	15
112.1	Induced variations by mutation	..	..	..	1	2	..	..	..	..	3
112.11	Physical treatments (radiation, etc.)	..	1	1	3	5	..	1	..	..	11
121	Utilization of selected variants by producing clonal lines	..	..	..	..	1	..	..	..	..	1
122	By producing seed	..	..	..	2	3	..	..	..	1	6
122.0	Seed production areas	..	..	..	1	2	..	..	..	..	3
122.1	Seed orchards	1	..	..	7	14	..	..	..	..	22
14	Fundamental genetic studies	..	..	..	3	..	..	..	..	..	3
141	Mode of inheritance	..	..	..	..	10	..	..	..	..	10
142	Reaction range	..	..	..	..	2	..	..	..	..	2
144	Evolution	..	..	..	..	1	..	..	..	..	1
151.0	Physiology	..	..	..	..	8	..	..	..	..	8
151.01	Flower induction	1	..	1	6	10	..	..	..	..	18
151.02	Vegetative propagation	1	..	1	5	10	..	..	..	..	17
151.03	Nutritional studies	..	..	..	1	1	..	..	..	..	2
151.04	Photoperiodism	..	..	..	3	2	..	..	..	..	5
151.05	Thermoperiodism	..	..	..	1	..	..	..	..	..	1
151.07	Drought resistance	..	..	..	..	1	..	..	..	..	1
151.08	Phenology	..	..	..	3	3	..	..	..	..	6
151.1	Cytology	..	..	..	5	..	..	..	..	..	5
151.3	Morphology and anatomy	..	..	..	1	5	..	..	..	..	6
151.32	Wood characteristics	..	..	..	..	3	..	..	..	..	3
151.321	Wood density	..	..	..	..	1	..	..	..	1	2
153	Biometry	..	..	..	..	..	..	..	..	1	1
151.4	Ecology	..	..	..	..	1	..	..	..	..	1
154	Special techniques	..	..	..	..	..	..	..	..	1	1
151.5	Pathology	1	..	1	3	18	..	..	..	..	23
152.0	Entomology	..	..	..	..	5	..	..	..	..	5
154.0	Controlled pollination	..	..	..	4	..	..	..	..	..	4
154.03	Flower bagging	..	..	..	..	1	..	..	..	..	1
154.2	Nursery techniques	..	..	..	2	2	..	..	..	..	4
	Total	10	3	43	104	233	2	3	1	5	404

1/ If a study concerns more than one species, it is tallied for each species; hence the numbers here are greater than the total number of projects.

Table 2B.--Projects by categories and genera (hardwoods)[1/]

	Category	Acer	Betula	Celtis	Fraxinus	Hemiptelea	Holoptelea	Populus	Quercus	Trema	Ulmus	Zelkova	General	Total
211	Natural variation	..	..	..	..	..	..	3	..	..	..	..	..	3
211.0	Natural variation among species	..	1	1	..	1	1	11	..	1	1	1	1	19
211.1	Natural variation among races	1	4	..	1	..	..	13	3	..	..	..	..	22
211.2	Natural variation among stands	..	..	..	..	..	..	1	..	..	..	..	..	1
211.3	Natural variation among individuals	..	1	1	..	1	1	7	5	1	1	1	..	19
212	Induced variation	..	..	..	..	..	..	3	..	..	..	..	..	3
212.0	Induced variation by recombination	..	2	1	..	1	1	4	..	1	1	1	..	12
212.01	Interspecific hybridization	..	..	..	..	..	..	8	..	..	..	..	..	8
212.02	Intraspecific hybridization	..	..	..	..	..	..	1	..	..	..	..	..	1
212.11	Induced variation by mutation	..	1	..	..	..	..	..	..	..	..	..	..	1
221	Utilization of selected variants by producing clonal lines	..	..	..	..	..	..	4	..	..	..	..	1	5
222	By producing seed	..	..	..	..	..	..	2	..	..	..	..	..	2
23	Applications of genetics in silviculture	..	..	..	..	..	..	1	..	..	..	..	..	1
24	Fundamental genetic studies	..	1	..	..	..	..	2	..	..	..	..	..	3
243	Experimental taxonomy	..	..	..	..	..	..	2	..	..	..	..	..	2
251.0	Physiology	..	1	..	..	..	..	2	..	..	..	..	..	3
251.01	Flower induction	..	..	..	..	..	..	2	..	..	..	..	..	2
251.02	Vegetative propagation	..	..	..	..	..	..	3	..	..	..	..	..	3
251.03	Nutritional studies	..	..	..	..	..	..	3	..	..	..	..	..	3
251.08	Phenology	..	..	..	..	..	..	1	..	..	..	..	..	1
251.1	Cytology	..	..	..	..	..	..	6	..	..	..	..	..	6
251.3	Morphology and anatomy	..	1	..	..	..	..	1	..	..	..	..	..	2
251.32	Wood characteristics	1	..	..	1	..	..	9	..	..	..	..	..	11
251.4	Ecology	..	..	..	..	..	..	1	..	..	..	..	..	1
251.5	Pathology	..	..	1	..	1	1	1	..	1	1	1	..	7
254.04	Methods of controlled pollination	..	..	..	..	..	..	1	..	..	..	..	..	1
	Total	2	12	4	2	4	4	92	8	4	4	4	2	142

1/ If a study concerns more than one species, it is tallied for each species; hence the numbers here exceed the total number of projects.

Table 3A.--Pinus projects by agencies and species

	Agency	banksiana	cembra	contorta	elliottii	flexilis	griffithii	koraiensis	montana	monticola	nigra
2.	Inst. of Paper Chemistry	..	..	..	..	..	..	..	..	..	..
3.	Mich. State Univ.	3	..	..	..	1	..	..	..	..	2
4.	Mich. Technol. Univ.	..	..	..	..	..	..	..	..	..	1
5.	Minn. Dept. of Conserv.	..	..	..	..	..	..	..	..	..	..
6.	Nekoosa-Edwards Paper Co.	2	..	..	..	..	..	..	..	..	..
7.	Quetico-Superior Wilderness Res. Center	1	1	..	..	..	1	1	1	..	..
8.	U.S. Forest Prod. Lab.	..	..	..	..	..	..	..	..	..	..
9.	U.S. Lake States Forest Expt. Sta.	8	..	2	..	1	..	1	..	1	..
10.	Univ. of Mich.	1	..	..	..	..	..	..	..	..	..
11.	Univ. of Minn.	6	..	1	2	..	..	..	..	..	..
12.	Univ. of Wis.	1	..	..	..	..	..	..	..	..	1
13.	Kimberly-Clark Corp.	..	..	..	..	..	..	..	..	..	..
14.	Mando Div. of Boise Cascade Corp.	1	..	..	..	..	..	..	..	..	..
15.	Nekoosa-Edwards Paper Co.	..	..	..	..	..	..	..	..	..	..
16.	U.S. Forest Serv., No. Cent. Region	1	..	..	..	..	..	..	..	..	..
	Total	24	1	3	2	2	1	2	1	1	4

Table 3A cont'd.

	Agency	peuce	ponderosa	resinosa	rigida	strobiformis	strobus	sylvestris	taeda	virginiana	Species	Total
2.	Inst. of Paper Chemistry	..	..	..	..	..	..	..	1	..	..	1
3.	Mich. State Univ.	..	1	2	..	1	2	3	..	1	..	16
4.	Mich. Technol. Univ.	..	1	1	..	..	1	1	..	..	..	5
5.	Minn. Dept. of Conserv.	..	..	1	..	..	..	..	..	..	..	1
6.	Nekoosa-Edwards Paper Co.	..	..	1	..	..	..	..	..	..	..	3
7.	Quetico-Superior Wilderness Res. Center	2	..	1	..	..	2	1	..	..	..	11
8.	U.S. Forest Prod. Lab.	..	..	1	..	..	..	..	..	..	..	1
9.	U.S. Lake States Forest Expt. Sta.	1	3	10	..	..	5	3	..	..	..	35
10.	Univ. of Mich.	..	..	..	..	..	..	..	..	..	..	1
11.	Univ. of Minn.	..	1	1	1	..	..	3	1	1	1	18
12.	Univ. of Wis.	..	1	3	..	..	1	1	..	..	1	9
13.	Kimberly-Clark Corp.	..	..	1	..	..	..	..	..	..	..	1
14.	Mando Div. of Boise Cascade Corp.	..	..	1	..	..	1	..	..	..	..	3
15.	Nekoosa-Edwards Paper Co.	..	..	1	..	..	..	..	..	..	..	1
16.	U.S. Forest Serv, No. Cent. Region	..	..	3	..	..	3	..	..	..	..	7
	Total	3	7	27	1	1	15	12	2	2	2	113

Table 3B.--Picea projects by agencies and species

Agency	abies	engel-manni	glauca	glehni	mariana	obovata	omorika	orient-alis	pungens	rubens	Total
1. Consolidated Papers, Inc.	..	..	1	..	..	..	..	..	..	..	1
3. Mich. State Univ.	1	..	1	..	..	..	..	..	..	1	3
4. Mich. Technol. Univ.	..	..	2	..	..	..	..	..	..	..	2
5. Minn. Dept. of Conserv.	..	..	1	..	..	..	..	..	..	..	1
6. Nekoosa-Edwards Paper Co.	..	..	1	..	1	..	..	..	..	..	2
7. Quetico-Superior Wilderness Res. Center	1	..	1	..	1	..	..	..	..	..	3
9. U.S. Lake States Forest Expt. Sta.	4	1	13	1	4	2	2	1	1	3	32
11. Univ. of Minn.	1	..	5	..	3	..	..	..	1	1	11
13. Kimberly-Clark Corp.	..	..	1	..	1	..	..	..	..	..	2
14. Mando Div. of Boise Cascade Corp.	..	..	1	..	1	..	..	..	..	..	2
16. U.S. Forest Serv., No. Cent. Region	..	..	2	..	1	..	..	..	..	..	3
Total	7	1	29	1	12	2	2	1	2	5	62

Table 3C.--Populus projects by agencies and species

Agency	aden-opoda	alba	canescens	del-toides	grandi-dentata	tremula	tremu-loides	tricho-carpa	sie-boldii	species	Total
2. Instit. of Paper Chemistry	..	..	1	2	2	..	4	..	..	1	10
3. Mich. State Univ.	..	..	..	1	..	..	..	..	..	..	1
8. U.S. Forest Prod. Lab.	..	..	..	..	..	..	..	..	..	2	2
10. Univ. of Mich.	..	..	..	..	3	..	2	..	..	..	5
11. Univ. of Minn.	1	1	1	..	1	1	3	1	1	2	12
12. Univ. of Wis.	..	..	..	2	..	..	1	..	..	2	5
14. Mando Div. of Boise Cascade Corp.	..	..	..	..	..	..	1	..	..	..	1
Total	1	1	2	5	6	1	11	1	1	7	36

Table 4A.--Pinus projects by categories and species

	Category	banksiana	cembra	contorta	elliottii	flexilis	griffithii	koraiensis	montana	monticola	nigra
111	Natural variation	2	..	..	..	..	..	..	..	..	..
111.0	Natural variation among species	3	1	1	..	..	1	1	1	..	1
111.1	Natural variation among races	13	..	..	1	2	..	1	..	..	3
111.2	Natural variation among stands	..	..	..	1	..	..	..	..	..	..
111.3	Natural variation among individuals	4	..	..	1	..	..	..	..	..	..
112.0	Induced variation by recombination	..	..	1	..	..	..	..	..	..	..
112.01	Interspecific hybridization	2	..	1	..	..	..	..	..	1	1
112.02	Intraspecific hybridization	1	1	..	..	..	1	1	1	..	..
112.1	Induced variation by mutation	1	..	..	..	..	..	..	..	..	..
112.11	Physical treatments (radiation, etc.)	3	..	..	..	..	..	..	..	..	..
121	Utilization of selected variants by producing clonal lines	..	..	..	..	..	..	..	..	..	..
122	By producing seed	..	..	..	..	..	..	..	..	..	..
122.0	Seed production areas	..	..	..	..	..	..	..	..	..	..
122.1	Seed orchards	3	..	..	..	..	..	..	..	..	..
141	Mode of inheritance	5	..	..	1	..	..	..	..	..	..
142	Reaction range	..	..	..	..	..	..	..	..	..	..
144	Evolution	..	..	..	..	..	..	..	..	..	..
151.0	Physiology	2	..	..	..	..	..	..	..	..	1
151.01	Flower induction	1	1	..	..	..	1	1	1	..	..
151.02	Vegetative propagation	1	1	..	..	..	1	1	1	..	..
151.03	Nutritional studies	..	..	..	..	..	..	..	..	..	..
151.04	Photoperiodism	..	..	..	..	..	..	..	..	..	..
151.07	Drought resistance	..	..	..	..	..	..	..	..	..	..
151.08	Phenology	..	..	..	..	..	..	..	..	..	..
151.3	Morphology and anatomy	2	..	..	..	..	..	..	..	..	..
151.32	Wood characteristics	..	..	..	..	..	..	..	..	..	..
151.321	Wood density	..	..	..	..	..	..	..	..	..	..
151.4	Ecology	1	..	..	..	..	..	..	..	..	..
151.5	Pathology	2	1	..	..	1	1	2	1	..	..
152.0	Entomology	1	..	..	..	..	..	..	..	..	..
154.03	Bagging flowers	..	..	..	..	..	..	..	..	..	..
154.2	Nursery techniques	..	..	..	..	..	..	..	..	..	..
	Total	47	5	3	4	3	5	7	5	1	6

(CONTINUED ON NEXT PAGE)

Table 4A cont'd.

	Category	peuce	ponder-osa	resin-osa	rigida	strobi-formis	stro-bus	sylves-tris	taeda	virgin-iana	Species	Total
111	Natural variation	..	..	2	..	..	1	..	..	..	..	5
111.0	Natural variation among species	1	2	3	1	..	1	3	..	1	..	21
111.1	Natural variation among races	1	6	10	..	1	6	9	..	1	..	54
111.2	Natural variation among stands	..	..	..	..	..	..	..	1	..	..	2
111.3	Natural variation among individuals	..	..	3	..	..	4	1	1	..	..	14
112.0	Induced variation by recombination	..	1	1	1	..	1	..	..	1	..	6
112.01	Interspecific hybridization	..	..	2	..	..	2	1	..	..	..	10
112.02	Intraspecific hybridization	1	..	1	..	..	2	1	..	..	..	10
112.1	Induced variation by mutation	..	..	1	..	..	..	..	..	..	..	2
112.11	Physical treatments (radiation, etc.)	..	..	1	..	..	1	..	..	..	..	5
121	Utilization of selected variants by producing clonal lines	..	..	..	..	..	..	..	1	..	..	1
122	By producing seed	..	..	3	..	..	..	..	..	..	..	3
122.0	Seed production areas	..	..	1	..	..	1	..	..	..	..	2
122.1	Seed orchards	..	..	6	..	..	4	1	..	..	..	14
141	Mode of inheritance	..	..	1	..	..	1	1	1	..	..	10
142	Reaction range	..	..	..	..	..	..	..	1	..	1	2
144	Evolution	..	..	..	..	..	..	1	..	..	..	1
151.0	Physiology	..	..	3	..	..	..	1	..	..	1	8
151.01	Flower induction	1	1	1	..	..	1	1	..	..	..	10
151.02	Vegetative propagation	1	..	1	..	..	2	1	..	..	..	10
151.03	Nutritional studies	..	..	1	..	..	..	..	..	..	..	1
151.04	Photoperiodism	..	..	1	..	..	1	..	..	..	..	2
151.07	Drought resistance	..	1	..	..	..	..	..	..	..	..	1
151.08	Phenology	..	..	1	..	..	..	1	..	..	1	3
151.3	Morphology and anatomy	..	1	..	..	..	..	..	..	..	2	5
151.32	Wood characteristics	..	..	2	..	..	..	..	1	..	..	3
151.321	Wood density	..	..	1	..	..	..	..	..	..	..	1
151.4	Ecology	..	..	..	..	..	..	..	..	..	..	1
151.5	Pathology	3	..	1	..	..	6	..	..	..	..	18
152.0	Entomology	..	1	3	..	..	..	..	..	..	..	5
154.03	Bagging flowers	..	..	1	..	..	..	..	..	..	..	1
154.2	Nursery techniques	..	..	1	..	..	1	..	..	..	..	2
	Total	8	13	52	2	1	35	22	6	3	5	233

Table 4B.--Picea projects by categories and species

	Category	abies	engelmanni	glauca	glehni	mariana	obovata	omorika	orientalis	pungens	rubens	Total
111	Natural variation	..	..	1	..	1	..	..	..	..	..	2
111.0	Natural variation among species	3	..	4	1	2	1	1	1	..	1	14
111.1	Natural variation among races	6	1	8	..	2	..	..	1	1	3	22
111.3	Natural variation among individuals	..	..	2	..	1	..	..	..	..	..	3
112	Induced variation	..	..	1	..	..	..	..	..	..	..	1
112.0	Induced variation by recombination	..	1	2	..	1	..	1	..	..	1	6
112.01	Interspecific hybridization	..	..	1	..	1	..	..	..	..	..	2
112.02	Intraspecific hybridization	1	..	1	..	1	..	..	..	..	..	3
112.1	Induced variation by mutation	..	..	1	..	..	..	..	..	..	..	1
112.11	Physical treatments (radiation, etc.)	1	..	2	..	..	..	..	..	..	..	3
122	Utilization of selected variants by producing seed	..	..	2	..	..	..	..	..	..	..	2
122.0	Seed production areas	..	..	1	..	..	..	..	..	..	..	1
122.1	Seed orchards	..	..	4	..	3	..	..	..	..	..	7
14	Fundamental genetic studies	..	..	2	..	1	..	..	..	..	..	3
151.01	Physiology - flower induction	1	..	2	..	2	..	..	..	1	..	6
151.02	Vegetative propagation	1	..	3	..	1	..	..	..	..	..	5
151.03	Nutritional studies	..	..	1	..	..	..	..	..	..	..	1
151.04	Photoperiodism	..	..	2	..	1	..	..	..	..	..	3
151.05	Thermoperiodism	..	..	1	..	..	..	..	..	..	..	1
151.08	Phenology	..	..	3	..	..	..	..	..	..	..	3
151.1	Cytology	..	..	3	..	2	..	..	..	..	..	5
151.3	Morphology and anatomy	..	..	..	..	..	..	..	..	1	..	1
151.5	Pathology	1	..	1	..	1	..	..	..	..	..	3
154.0	Controlled pollination	..	..	1	..	1	..	1	..	..	1	4
154.2	Nursery techniques	..	..	1	..	1	..	..	..	..	..	2
	Total	14	2	50	1	22	1	3	2	3	6	104

Table 4C.--Populus projects by categories and species

	Category	adenopoda	alba	canescens	deltoides	grandidentata	tremula	tremuloides	trichocarpa	sieboldii	Spp.	Total
211	Natural variation	..	..	..	1	1	..	1	..	..	..	3
211.0	Natural variation among species	1	1	1	..	2	1	2	..	1	2	11
211.1	Natural variation among races	1	1	1	2	2	1	3	..	1	1	13
211.2	Natural variation among stands	..	..	..	..	..	..	1	..	..	..	1
211.3	Natural variation among individuals	..	..	..	..	3	..	2	..	..	2	7
212	Induced variation	..	..	..	1	1	..	1	..	..	..	3
212.0	By recombination	..	..	1	..	1	..	1	..	..	1	4
212.01	Interspecific hybridization	..	..	..	1	2	..	3	..	..	2	8
212.02	Intraspecific hybridization	..	..	..	..	..	..	..	..	..	1	1
221	Utilization of selected variants by producing clonal lines	..	..	..	..	1	..	1	..	..	2	4
222	By producing seed	..	..	..	1	..	..	1	..	..	..	2
23	Application of genetics in silviculture	..	..	..	..	1	..	..	..	..	..	1
24	Fundamental genetic studies	..	..	..	..	..	..	1	1	..	..	2
243	Experimental taxonomy	..	..	..	..	1	..	1	..	..	..	2
251.0	Physiology	..	..	..	..	..	..	1	..	..	1	2
251.01	Flower induction	..	..	..	..	1	..	1	..	..	..	2
251.02	Vegetation propagation	..	..	..	..	1	..	2	..	..	..	3
251.03	Nutritional studies	..	..	1	..	1	..	1	..	..	..	3
251.08	Phenology	..	..	..	..	..	..	..	1	..	..	1
251.1	Cytology	..	..	..	2	..	..	2	..	..	2	6
251.3	Morphology and anatomy	..	..	..	..	..	..	1	..	..	..	1
251.32	Wood characteristics	..	..	..	1	2	..	4	..	..	2	9
251.4	Ecology	..	..	..	..	..	..	1	..	..	..	1
251.5	Pathology	..	..	..	..	..	..	..	..	..	1	1
254.04	Methods of controlled pollination	..	..	..	..	..	..	..	..	..	1	1
	Total	2	2	4	9	20	2	31	2	2	18	92

A GENERAL SUMMARY

The information summarized in Tables 1 through 4 gives the following general picture of forest tree improvement research and development work in the Lake States as of 1965.[5]

1. Almost three-quarters (73 percent) of the projects are concerned with 3 genera, in this order, *Pinus, Picea,* and *Populus.* About 25 percent of the studies deal with 16 other genera, and a little over 2 percent are general in nature. Out of the total projects reported, some 92 percent are research projects and 8 percent developmental.

2. Two-thirds of the studies involving pines concern the jack, red, and white pines native to the Lake States. Although 16 other pine species are included, only Scotch pine is very commonly represented. *Pinus resinosa* (24 percent of the pine studies) is receiving greatest attention; but *P. banksiana* (21 percent) is almost as well represented. Of the three native pines, *Pinus strobus* (13 percent) is receiving least attention.

3. The native white and black spruces are involved in two-thirds of the studies concerning *Picea* (*Picea glauca,* 46 percent, and *P. mariana,* 20 percent). Norway spruce (11 percent) and seven other spruces make up the other third.

4. Almost half the *Populus* studies (47 percent) concern quaking and bigtooth aspens. The other half involve seven *Populus* species and a number of hybrids.

5. Some 60 percent of the total number of studies concern variation. More than one-third of these involve racial variation. About 4 percent of the studies are in fundamental genetics, about 7 percent have to do with utilization of selected variants (primarily seed production areas and seed orchards), and the remaining 29 percent are in the categories of supporting sciences (particularly plant physiology) and special techniques.

6. Not only does the number of studies involving the pines, spruces, and poplars exceed those of other genera, but also more subject-matter categories are represented in them than in the studies of any other genera. For example, 32 subject-matter categories pertain to pine studies compared to 25 each for spruce studies and poplar studies.

7. As compared to the 1959 survey: (a) There has been little change in the proportion of studies concerning (1) the 3 genera (*Pinus, Picea,* and *Populus*), (2) the native pines (*Pinus resinosa, P. banksiana,* and *P. strobus*), (3) the native spruces (*Picea glauca* and *P. mariana*), (4) racial variation, (5) fundamental genetics, (6) or the emphasis on physiology among the supporting sciences; but (b) there has been a substantial increase in the number of studies, the number of research workers involved, the number of species covered, and the number of categories pertaining to the principal species, and some increase in the proportion of all studies concerning variation. There has been a start at developmental work by several agencies. Not shown in the statistics is an increase in amount and sophistication of special equipment and facilities for tree improvement research in the Lake States.

[5] *The figures given in the tables cannot necessarily be cross checked between tables because in some a study is listed for each category and species which apply to it and in others it is listed by applicable agency and species only.*

SUBJECT-MATTER CLASSIFICATION OF FOREST TREE IMPROVEMENT RESEARCH PROJECTS

1 I. Softwoods
11 A. Selection and testing of variation
111 1. Natural variation
111.0 a. Among species
111.1 b. Among races (ecotypes)
111.2 c. Among stands
111.3 d. Among individuals
112 2. Induced variation
112.0 a. By recombination
112.01 (1) Interspecific hybridization
112.02 (2) Intraspecific hybridization
112.03 (3) Selfing
112.1 b. By mutation
112.11 (1) Physical treatments (radiation, etc.)
(2) Chemical treatments (colchicine, etc.)

12 B. Utilization of selected variants for planting by production of
121 1. Clonal lines
122 2. Seed
122.0 a. Seed production areas
122.1 b. Seed orchards
122.2 3. Registered seed

13 C. Applications of genetics in silviculture and management of naturally reproduced stands

14 D. Fundamental genetic studies
141 1. Mode of inheritance
142 2. Reaction range
143 3. Experimental taxonomy
144 4. Evolution

15 E. Supporting sciences and special techniques
151 1. Botany
151.0 a. Physiology
151.01 (1) Flower induction
151.02 (2) Vegetative propagation
151.03 (3) Nutritional studies
151.04 (4) Photoperiodism
151.05 (5) Thermoperiodism
151.06 (6) Chemistry
151.07 (7) Drought resistance
151.08 (8) Phenology
151.09 (9) etc.....
151.1 b. Cytology
151.11 (1) Chromosome numbers
(2) etc.....

151.2 c. Taxonomy
(1) etc.....
151.3 d. Morphology and anatomy
151.31 (1) Flower primordia
151.32 (2) Wood characteristics
151.321 (a) Density
151.322 (b) Fiber length
151.323 (c) Fibril angle
151.324 (d) Heartwood, sapwood
151.325 (e) Compression wood
151.331 (1) Agamospermy
(2) etc.....
151.332 (1) Vegetative reproduction
(2) etc.....
151.34 (1) Leaves
(2) etc.....
151.4 e. Ecology
151.5 f. Pathology

152 2. Zoology
152.0 a. Entomology

153 3. Biometry

154 4. Special techniques
154.0 a. Controlled pollination
154.01 (1) Pollen collection
154.02 (2) Pollen storage
154.03 (3) Bagging
154.04 (4) Methods
154.1 b. Climbing gear
154.2 c. Nursery techniques

2 II. Hardwoods
21 A. Selection and testing of variation
211 1. Natural variation
211.0 a. Among species
211.1 b. Among races (ecotypes)
(As in Softwoods)
251.325 c. Tension wood

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- 212.0 Induced variation by recombination, 12
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- 211.3 Natural variation among individuals, 12
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PUBLICATIONS ISSUED FOR THE LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE

Proceedings, Lake States Forest Genetics Conference, March 30 - April 1, 1953. Lake States Forest Expt. Sta. Misc. Rpt. 22, 83 pp. 1953.

Proceedings, Lake States Forest Tree Improvement Conference, August 30-31, 1955. Lake States Forest Expt. Sta. Misc. Rpt. 40, 108 pp., illus. 1955.

Forest Genetics in the Lake States, an Annotated Bibliography, by William J. Libby, Burton V. Barnes, and Stephen H. Spurr. Univ. Mich. School of Natural Resources (no series), 74 pp. 1956.

Guide for Selecting Superior Trees and Stands in the Lake States, by Paul O. Rudolf. Lake States Forest Expt. Sta., Sta. Paper 40, 32 pp., illus. 1956.

Forest Tree Seed Collection Zones for the Lake States. Mich. Dept. Conserv., Forest Div. (no series), 13 pp., illus. 1957.

Proceedings, Third Lake States Forest Tree Improvement Conference, Sept. 17-18, 1957. Lake States Forest Expt. Sta., Sta. Paper 58, 87 pp., illus. 1958.

Forest Tree Improvement Research in the Lake States; A Survey by the Lake States Forest Tree Improvement Committee. Lake States Forest Expt. Sta., Sta. Paper 74, 56 pp. 1959.

Registering and Marking Selections in the Lake States; A Report of a Sub-committee of the Lake States Forest Tree Improvement Committee, by Paul O. Rudolf and H. E. Ochsner. U.S. Forest Serv., North Central Region (no series), 9 pp. 1959.

Forest Tree Seed Certification in the United States; A Report of a Subcommittee of the Lake States Forest Tree Improvement Committee, by J. W. Macon. Consolidated Water Power and Paper Co. (no series), 3 pp. 1959.

Proceedings of the Fourth Lake States Forest Tree Improvement Conference, Oct. 6-7, 1959. Lake States Forest Expt. Sta., Sta. Paper 81, 60 pp., illus. 1960.

Proceedings of the Fifth Lake States Forest Tree Improvement Conference, Sept. 19 & 20, 1961. Lake States Forest Expt. Sta., Sta. Paper 98, 42 pp. 1962.

Report of the Seed Certification Subcommittee of the Lake States Forest Tree Improvement Committee, by W. H. Brener. Wisconsin Conserv. Dept. (no series), 4 pp. 1963.

Proceedings, Sixth Lake States Forest Tree Improvement Conference, Sept. 9-10, 1963. Lake States Forest Expt. Sta. (no series) 90 pp., illus. 1964.

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